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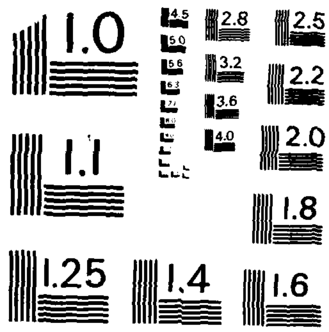

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HUMAN FACTORS IN THE MANAGEMENT OF BECON CONSTRUCTION COMPANY'S HEAVY OIL TEST STATION PROJECT

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Final Report, November 1986

A thesis submitted to The University of Texas at Austin in partial fulfillment of the requirements for the degree of Masters of Science in Engineering.

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A study was conducted to determine the learning curve effect on construction worker productivity at an open shop construction project involving the production of 92 identical heavy oil test stations at a 17 square mile oil field near Bakersfield, California. Additionally, the job satisfactions and dissatisfactions of the work force were identified, along with factors that effected them. Finally, various recommendations were made to retain for the 22-month project duration an experienced group of construction laborers.

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APPROVED:

HUMAN FACTORS IN THE MANAGEMENT OF BECON CONSTRUCTION COMPANY'S HEAVY OIL TEST STATION PROJECT

BY

DOUGLAS MAURER

THESIS

Presented to the Faculty of the Graduate School of

The University of Texas at Austin

in Partial Fulfillment

of the Requirements

for the Degree of

MASTER OF SCIENCE IN ENGINEERING

THE UNIVERSITY OF TEXAS AT AUSTIN

December 1986

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Douglas Maurer
November 1986

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CHAPTER 1. INTRODUCTION

1.1 Impetus for the Study

In January 1986, the Becon Construction Company - an open shop contractor based in Houston, Texas - mobilized a work force to a construction project location at the Belridge Oil Field, near Bakersfield, California. A unique aspect of the Becon project was the fact that it involved the construction of 87 essentially identical heavy oil test stations (HOTS) at individual locations throughout a 17 square mile oil field, owned and operated by Shell California Production, Incorporatd (SCPI). Even more intriguing was the nature of the construction operation: the same civil crew, electrical crew, mechanical crew, and prefabrication crew would construct each site during the project's scheduled 22 month duration. Thus, the construction craftsmen and helpers in Becon's work force were expected to improve their level of productivity as the work proceeded because of the knowledge and skills that they would acquire as a result of the repetitive nature of the work.[1] This "improvement in worker proficiency with practice"[2] was first noted by T. P. Wright in 1936 in his report concerning the production of small airplanes. Since then, this phenomenon has come to be known as the learning curve effect.

Prior to World War II learning curve research was conducted mainly in the aircraft and shipbuilding industries. The post war

era yielded an expansion of learning curve studies into the manufacturing industry. Various phases of learning were identified, as shown in Figure 1, and explanations for these phases were proposed. However, not until 1965[3] was the learning curve phenomenon first studied in the construction industry. A second study in 1984[4] dealt with repetitive construction operations in Europe and the associated learning effect. These two studies proposed several factors contributing to the learning effect on the construction site; but, neither one statistically analyzed these factors. Moreover, the learning models prescribed by both of these studies were proven less than reliable during comprehensive testing performed by Dr. H. Randolph Thomas as part of his ongoing learning curve research at the Pennsylvania State University.[5] In fact, two of the objectives of Dr. Thomas's research specifically address factors affecting learning, and learning curve models:[6]

- o Identify the factors that contribute to changes in learning rates.
- o Determine the best generalized learning curve model for repetitive construction activities in commercial construction.

Hence, there exists a need to analyze cause-effect relationships between the influencing factors on learning rates and the learning curve phenomenon concerning construction worker productivity. Productivity at the job site is determined by an interaction of a number of parameters in addition to the learning effect, such as weather, overtime, absenteeism, and the nature of

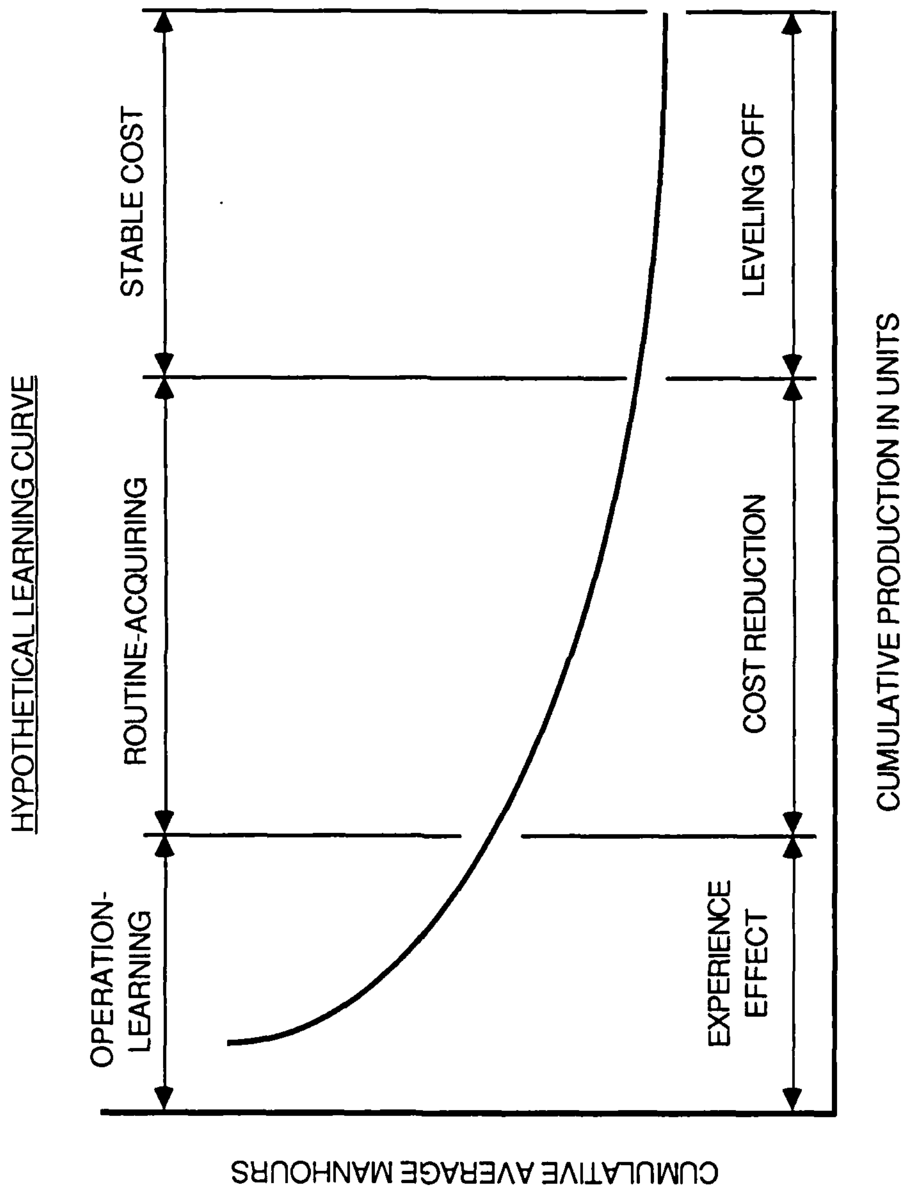


FIGURE 1

Hypothetical Learning Curve

the work. In order to apply a statistical methodology to the analysis of a construction activity's learning curve improvement, the link between the learning effect and these additional parameters must first be quantified. Then, these quantified parameters must be applied toward the definition of accurate activity forecasting models.[7] Consequently, Dr. Thomas's last two objectives for his research are as follows:[8]

- Quantify the interaction between learning and other conditions that contribute to inefficiencies.
- Quantify the range of values of the parameters that define the various predictive models as a function of important job site characteristics.

As it was originally organized, the Becon HOTS project represented almost a pure laboratory environment in which to collect data concerning the learning effect on worker productivity as well as to statistically isolate the impact on productivity of such external factors as weather, absenteeism, turnover, and especially work methods improvement techniques and pay incentives. From the outset of the HOTS project, the project manager had established an accurate system to quantitatively measure and compare the total manhours that each crew - civil, mechanical, electrical and prefabrication -- performed at individual HOTS construction locations. Additionally, it was initially assumed that the project manager would be relatively free to implement changes to the job site conditions involving incentive pay and work methods improvement. The subsequent effect of these changes on the productivity of

separate work crews could then be evaluated in terms of measured manhours per crew per HOTS. Therefore, coordination to study the Becon HOTS project was acomplished between Dr. John D. Borcherding, Associate Professor, University of Texas at Austin, and Mr. Charles R. Martin, Manager of Construction, Becon Construction Company.

1.2 Original Objectives of the Study

The objectives for the study of Becon's HOTS project as originally proposed to the construction site manager in April 1986 were as follows:

- To devise a detailed productivity measurement system -- complete with foremen delay surveys and craftsmen questionnaries -- for principal project activities.
- To implement this productivity measurement system at the project's prefabrication yard and HOTS sites.
- To evaluate productivity data in order to identify the learning curve effect on productivity levels.
- To perform a detailed work methods improvement analysis -- time lapse film, work sampling, flow diagram - process charts, crew balance study, and 5-minute ratings -- of selected craft activities at the prefabrication yard and the HOTS sites.
- To devise various proposals -- including the use of incentives -- to improve the productivity among selected crafts at the prefabrication yard and the HOTS sites.
- To implement work methods improvement proposals at the prefabrication yard and the HOTS sites.
- To measure and evaluate the effect of the implemented work methods improvement proposals on the productivity of selected crafts at the prefabrication yard and HOTS sites.

The Becon Site manager verbally approved these objectives shortly thereafter. Subsequently, he informed in writing his point of contact at SCPI of the pending study to be conducted at the HOTS project location.

1.3 Project Description

The construction site for the 87 heavy oil test stations is the Belridge Oil Field, owned and operated by Shell California Production, Incorporated. This oil field is situated approximately 50 miles west of Bakersfield, California as shown in Figure 2. The oil in the Belridge Field lies at shallow depths (500 feet or less) and has the viscosity of cold molasses. The most economical method to remove this thick, crude oil is to first inject steam into the ground, thereby heating the oil and lowering its viscosity. Thereupon, the less viscous crude oil is pumped to the surface where it must be monitored to determine its exact composition of oil, water, air, and sand particles.

The test stations curently in use at SCPI's Belridge field are extremely antiquated. On the other hand, the replacement HOTS being constructed by Becon Construction represent an application of state-of-the-art pneumatic and computer engineering. Each existing test station is to be replaced with a new system.

The new HOTS is basically a sophisticated flow meter. The system utilizes computer-operated valves and meters to continuously measure and record the composition of crude oil in flow lines from

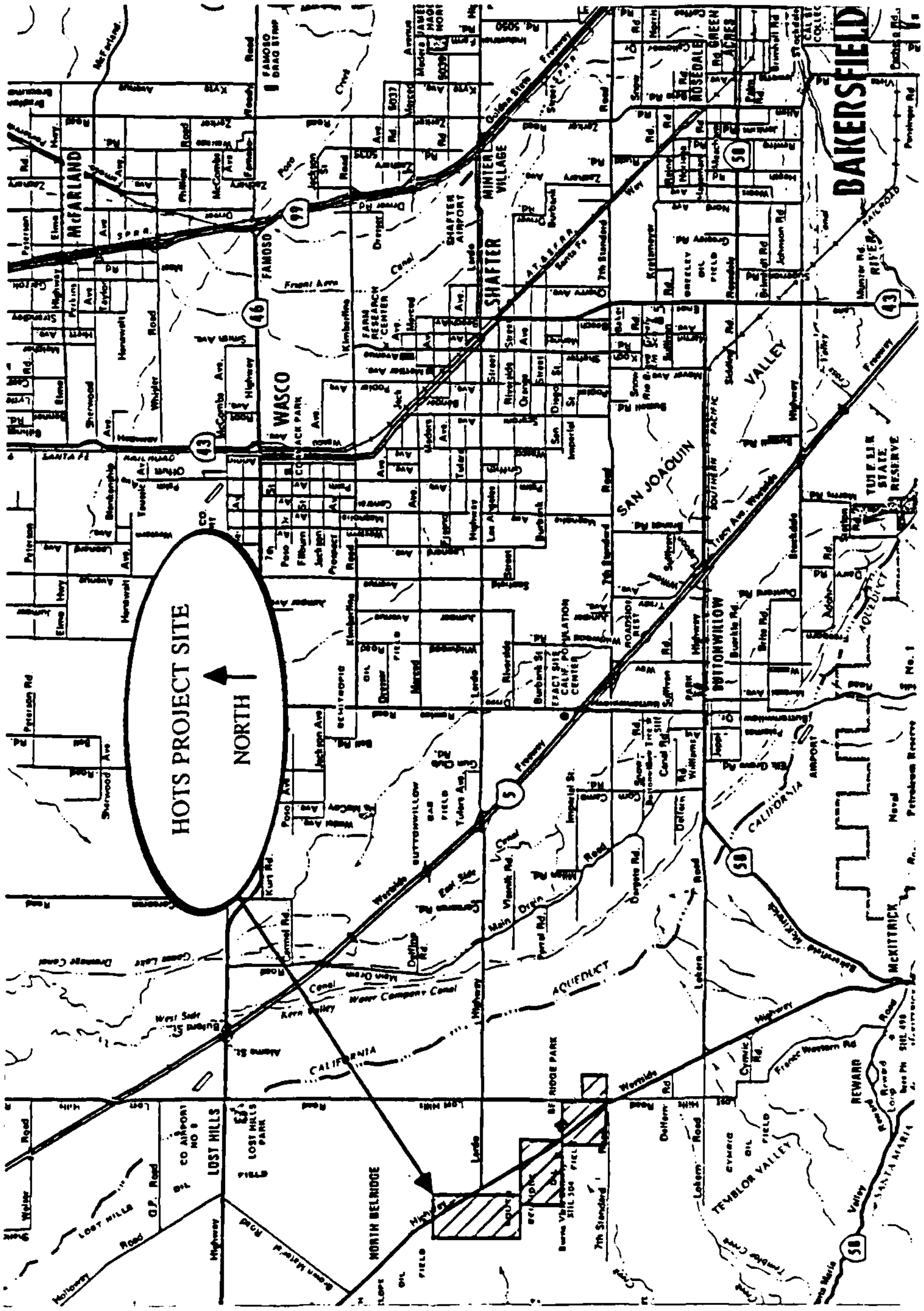


FIGURE 2

Site Map for the HOTS Project

any one of up to 50 oil wells in the local vicinity of the station. Hence, the manual labor requirements of the existing test stations -- monitoring control valves and recording measurements -- are totally eliminated by employment of the fully automated replacement HOTS.

The scope of construction for the HOTS project as prescribed in the bidding documents called for the completion of 87 sites scattered throughout the 17 square mile area of SCPI's Belridge Oil Field. The cost of construction was estimated at approximately $7 million. The scheduled start and completion dates were 15 January 1986 and 15 November 1987, respectively.

Each HOTS comprises 5400 square feet of area. The major engineered mechanical components to be installed on every site are an air compressor, a control panel, a separator tank, and from three to five 5-well or 10-well manifold skids, see Figure 3. SCPI is responsible for the procurement and delivery to Becon's project site of precast concrete items, engineered mechanical equipment, pipe, fittings, valves, instrument controls, and programmable computers. All other construction materials for each site are requisitioned by Becon's field project management.

Civil work required to complete work on a HOTS includes site preparation, installation of underground pipe and electrical conduit, placement of concrete footings for the manifold skids as well as placement of 3 concrete pads for the engineered equipment, and final site grading. The mechanical portion of a HOTS consists

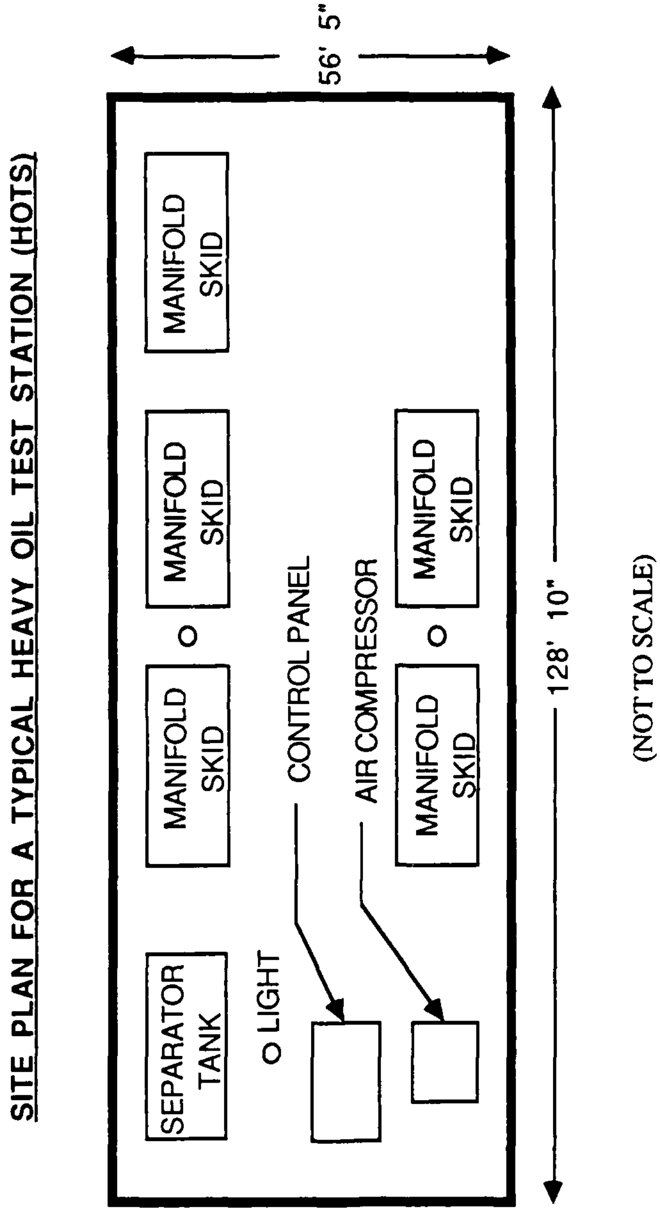


FIGURE 3

Site Plan for a Typical Heavy Oil Test Station (HOTS)

of setting the engineered equipment onto the concrete foundations, installing and testing the pipe that interconnects this equipment, and hanging pipe supports. Setting control panels and light poles, installing electrical conduit and wiring, and placing into service the instrumentation comprise the electrical phase of HOTS construction. The connection of the HOTS manifold skids to surrounding oil well flow lines is performed under the provisions of a separate SCPI contract by a contractor other than Becon.

1.4 Managing the Project

The field management set in place by the Becon Construction Company to run the HOTS project resembled the organizational structure of a small, owner-operated general contractor. The line chart for the HOTS project is shown in Figure 4. Enjoying the benefits of a shallow hierarchy, the HOTS field staff fostered an atmosphere commonly characteristic of most small to medium sized construction projects (less than $10,000,000.00): the free flow of communications among craftsmen, foremen, and management, the delegation of decision making authority to the foremen level, and the existence of mutual trust and confidence among craftsmen, foremen, and management.[9] This family-like atmosphere on the job site was enhanced by the fact that over 50% of the craftsmen and foremen employed on the project had worked for Becon Construction previously. Indeed, the project manager had personally recruited from as far away as Louisiana and Oklahoma several craftsmen formerly employed by Becon.

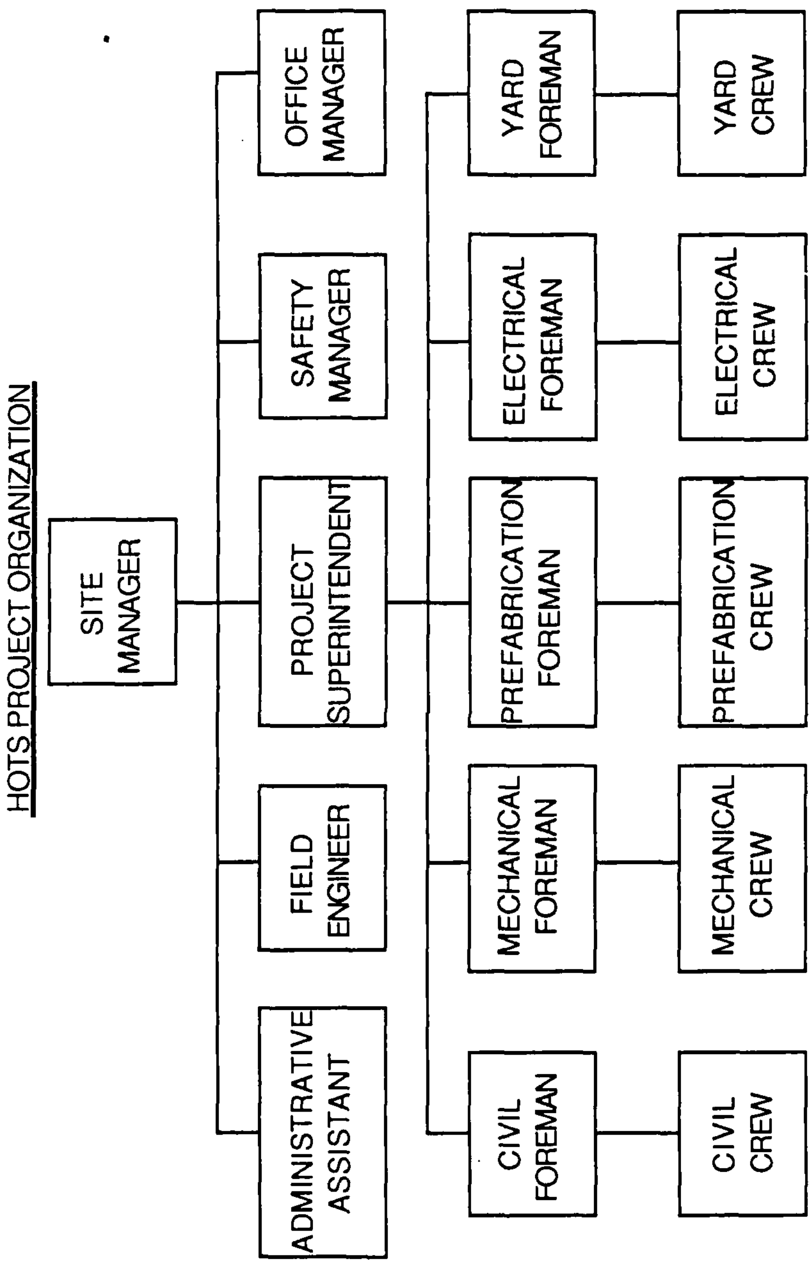


FIGURE 4

Organizational Line Chart for the HOTS Project

Moreover, craftsmen and foremen, alike, demonstrated innovative construction techniques as well as a willingness to attempt new, potentially more efficient work methods on the job site. In short, the HOTS project was a well managed, highly organized construction operation that represented an excellent opportunity for this study.

The original personnel manning plan called for the procurement of 50 craftsmen and helpers no later than week 12 of construction. This work force was to have remained constant for the remainder of the project until demobilization.

However, once the peak of 57 workers was achieved in March 1986, the project work force gradually attrited to a considerably lower figure by the end of August 1986. A plot of planned versus actual project manning from January 1986 to August 1986 is shown in Figure 5.

Becon's estimators calculated that to complete each HOTS would require 2104 direct work man-hours. A breakdown of this total by cost code is included in Table 1. The HOTS field management further distributed these direct work man-hours into field and prefabrication components, also indicated in Table 1. The project manager noted that the total of 2104 direct work man-hours did, in fact, reflect a reduction by 25% from the value originally calculated by Becon's estimators to complete one HOTS. This reduction represented an adjustment for the improvement in worker productivity with time that was expected to result from the repetitive nature of the construction: the learning curve effect.

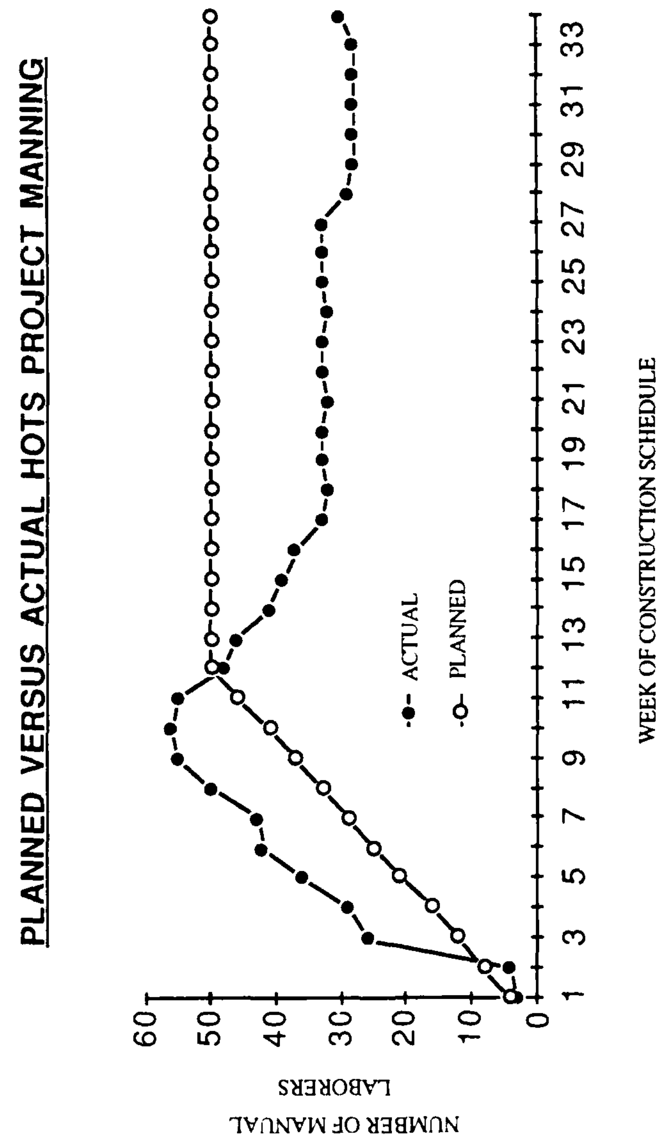


FIGURE 5

Planned versus Actual Project Manning
(January 1986 - August 1986)

Cost Code	Activity	Total Man-Hours	Field Man-Hours	Prefabrication Man-Hours
1000	Gravel	116	116	0
2000	Concrete	175	175	0
3000	Fabrication Steel	95	95	0
5000	Mechanical Equipment	178	178	0
6000	Pipe	770	450	320
7000	Electrical/ Instrumentation	684	571	113
8000	Paint	86	0	86
	TOTAL:	2104	1585	519

Table 1.

Estimated Direct Work Man-Hours to Compete a HOTS

The project work force was organized into 4 crews, as previously shown in Figure 4. Work hours were established by Becon's customer, SCPI, as 7:00 a.m. to 3:30 p.m., Monday through Friday. The HOTS project manager was unsuccessful in affecting a change to the total daily work hours, despite the fact that a second, unrelated Becon project at SCPI's Belridge Oil Field operated with a 4-10's work week. Neither did the HOTS project manager receive permission from SCPI to start and finish daily construction operations earlier during the hot summer months. Essentially, SCPI management wanted to insure that all workers in the Belridge Oil Field started and finished their daily activities at the same time.[10]

Weather proved to be a relatively insignificant factor in scheduling the HOTS construction. The Bakersfield area receives an

average of slightly less than six inches of rainfall annually, most of which occurs from October through April.[11] Therefore, minimal rain delays were anticipated. The extreme heat experienced during the summer months in the Bakersfield vicinity was expected to cause some fatigue in the three field construction crews. All civil, mechanical, and electrical work at each HOTS took place outdoors and at unshaded work sites. (The prefabrication operation was located in a shaded area.) Nevertheless, the project manager and the project safety officer had acquired considerable experience in the prevention and treatment of heat related injuries at a previous Becon construction site situated in the California desert. Consequently, the HOTS project was managed such that craftsmen and helpers received an ample supply of cool water on the job site, shade umbrellas were procured for the three field work crews, and workers were reminded during weekly tool box safety meetings about the symptoms and treatment of heat related injuries.

The HOTS construction schedule, as originally coordinated between Becon and SCPI managers, called for the construction of new test stations in groups of three. (SCPI had initially limited to three the number of existing test stations to be shut down during construction operations at any one time.) The construction of each group of 3 HOTS was to last 5 workweeks. Thus, every 35 calendar days Becon was to begin construction on a new group of 3 HOTS. Design information particular to the site plan for each new HOTS was forwarded incrementally to the HOTS project management in

groups of 9 sites per set of drawings. SCPI prepared these drawings by using both in-house and consultant engineering resources. Furthermore, the engineered mechanical components for each HOTS were also delivered incrementally by SCPI to Becon's project storage yard; SCPI's plan was to deliver to Becon the materials required for 10 sites every 10 weeks.

Hence, Becon's HOTS project manager was forced to constrain the construction schedule because of the dependency of work progress on SCPI providing design information and engineered mechanical components. Per SCPI's bid documents, the number of HOTS scheduled for completion in 1986 was 45, leaving 42 for completion in 1987, see Table 2. SCPI had good reason for this programmed constraint of Becon's HOTS construction progress: the procurement of engineered mechanical components by SCPI represented a considerable expense, one which was best spread over time considering the time value of money. It is also significant to note that during the initial few months of the HOTS project, the price of a barrel of crude oil dropped to its lowest level in almost 10 years[12], thus making spare capital a scarce item in the oil industry. Accordingly, in July 1986 SCPI directed that Becon shift the completion of 3 HOTS to calendar year 1987. In this way, SCPI delayed until 1987 the capital outlay for the procurement of materials for these 3 sites as well as for the cost to construct these sites, payable to Becon upon receipt by SCPI of each completed HOTS.

	Completion in 1986	Completion in 1987	Total
As Bid	45	42	87
Change #1, July 1986	42	46	88
Change #2, August 1986	48	44	92

TABLE 2.

HOTS Completion Schedule by Calendar Year

On the other hand, as the price of crude oil began to rise again in late summer 1986, SCPI ordered Becon to adjust the construction schedule once more, adding the 3 HOTS previously shifted to 1987 back to 1986 plus adding 3 new HOTS to 1986, see Table 2. The bottom line for the HOTS project manager was that the health of the oil industry and the time value of money worked together to constrain his ability to schedule the completion of HOTS construction.

The construction time table that ultimately evolved and met with SCPI's approval called for the start of one HOTS and the completion of another every workweek. The basic 5 workweek duration per HOTS remained unchanged; however, the sequencing of work trades at each HOTS greatly economized the utilization of Becon workers. Instead of employing enough craftsmen to perform similar construction activities on three sites simultaneously, a smaller

Becon work force was organized into three distinct field crews: civil, mechanical and electrical. These crews, then, succeeded one anotner on each site in accordance with a logical construction plan, see Figure 6.

Site preparation work, which was subcontracted by Becon to a Bakersfield firm, lasted one workweek. Thereupon, Becon's civil crew spent the second workweek preparing the concrete foundations and placing underground piping and electrical grounding. During the third workweek, the mechanical crew set the engineered mechanical equipment and installed the aboveground piping on the site. The electrical crew succeeded the mechanical crew during the fourtn week of construction, installing electrical conduit, pulling wire, and making electrical connections. The fifth workweek per site was spent painting aboveground piping, spreading gravel, and removing trash in anticipation of the site's final walk-through inspection by SCPI personnel. All the while, the prefabrication crew, consisting of pipefitters and welders, cut and fit enough pipe per week to supply at least one HOTS.

A new HOTS was transferred to SCPI every Wednesday under the revised work schedule. This schedule adequately accounted for the design information constraints imposed by SCPI on Becon. More importantly, the revised work plan enabled the HOTS project manager to more logically organize his work force and their construction activities.

CONSTRUCTION SCHEDULE FOR A TYPICAL HOTS

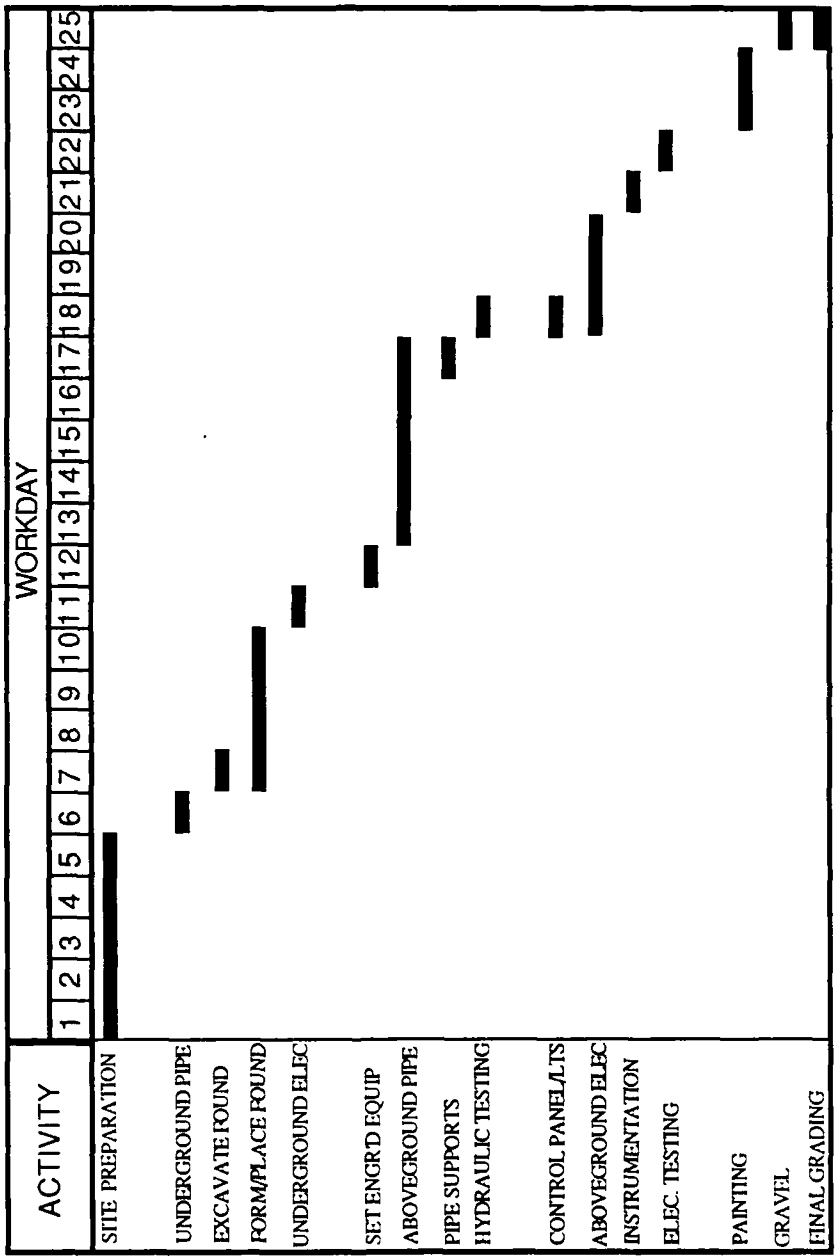


FIGURE 6

Bar Chart Construction Schedule for a HOTS

With this improved organization of his work force, the HOTS project manager was faced with a different problem. The civil, electrical, and prefabrication crews often progressed at a rate faster than dictated by the revised schedule. Conceivably, these crews could have worked themselves out of a job because of the constrained availability of design information and SCPI-supplied materials. If that happened, the project manager would be forced to lay off the idle workers until the next increment of design information and engineered components was delivered. Or, the project manager could reassign these idle workers to other Becon construction projects in the area.

Because of the transient nature of his work force, the HOTS project manager knew that if he laid off any of his workers for a considerable length of time, they would not wait to be rehired at the HOTS project. Instead, they would seek any available work, whether in the Bakersfield area or not. Thus, the project manager risked losing a tremendous wealth of HOTS construction expertise if ever he laid off a work crew that had essentially run out of work. Similarly, the new craftsmen eventually hired to replace the laid off workers would require some construction experience before improving their productivity as a result of the learning curve effect. Furthermore, the limited availability of construction craftsmen for hire by an open shop contractor -- as opposed to characteristically ready, union labor pools -- was also a constraint on the site manager's ability to procure replacement workers.

Accordingly, the HOTS project manager chose to reassign idle construction crews to other Becon projects at the Belridge Oil Field. For instance, both the civil and prefabrication crews were loaned to the second Becon project at the oil field for almost a week in mid July 1986; they helped to crash additional work that had been acquired on a very tight schedule. The man-hours of these crews were, quite naturally, charged to the second Becon job and not to the HOTS project. Yet, the HOTS project manager was able to retain on Becon's payroll two crews experienced in HOTS construction, despite the fact that these crews had nearly run out of work on the HOTS project. In early August, the HOTS project manager bid on and won the award from SCPI of a $15,000.00 contract to construct a small vapor recovery system at the oil field's power plant. For nearly two weeks in late August, the civil, electrical, and prefabrication crews were employed on this vapor recovery construction project. In the meantime, sufficient design information arrived to enable these crews to proceed with HOTS construction once the recovery system had been completed. A bid for still another small scale SCPI construction contract was submitted by the HOTS project manager for Becon in late August.

This, then, was one of the project manager's objectives for managing the HOTS project: to abide by the HOTS completion constraints imposed by SCPI, while aggressively seeking to retain a cohesive, knowledgeable work force for the duration of the project. Recognizing in late March that this work force had grown larger

than that required by such an objective, the project manager made a conscious decision not to have a major layoff of workers in order to reduce the number of HOTS craftsmen. Instead, he expected a natural attrition of workers to occur, thereby lowering his payroll. In the meantime, maintaining a larger than required work force supported his basic view that it was advantageous to gain planning flexibility at the expense of a certain degree of efficiency at the workplace. For example, the HOTS project manager was more likely to employ three welders on the job even though only two welders were required. He justified maintaining the seemingly additional welder because this welder represented the capability to carry on with construction activities as scheduled in the event of the absence of one of the welders. Indeed, the relatively small scale of the HOTS project work force created a situation in which worker absences or injuries could create critical shortages among the project craftsmen.

1.5 Change in the Study's Focus

The HOTS project work force did, in fact, undergo a great degree of attrition in April 1986; whereas, no additional craftsmen or helpers were hired during the same period. By 12 May 1986, HOTS project crew members totalled 32, down from an employment level of 56 workers near the end of March 1986. It was then that the project manager voiced two concerns regarding the original objectives of this study. First of all, he was opposed to laying off any of his crew members merely to improve

the efficiency of project construction operations. Such layoffs, he felt, would do more damage than good in the long run. To remove any additional workers from his payroll, the HOTS project manager contended, would lower the morale of those remaining on the payroll because of the appearance that their job security was being threatened by this study. In addition, the project manager felt strongly that further worker layoffs would eliminate his flexibility with which to manage project activities in the event of undesirable contingencies such as absence or injury.

Secondly, the HOTS project manager felt that the use of incentive pay on the project was no longer feasible. The obvious reason for this infeasibility was the fact that incentives could encourage the crews to proceed faster than the constrained schedule would allow. Moreover, several cost factors had been omitted by Becon estimators when they prepared the HOTS project bid. Consequently, the bid price that was submitted to SCPI was lower than it should have been. Granted, these omissions may have been responsible for Becon winning the award of the HOTS contract in the first place; however, the omitted costs could not be charged to SCPI during the actual HOTS construction. Instead, the project manager was committed to carefully managing the construction efforts of his work crews so as to earn profit enough to balance the unbudgeted expenditures represented by the costs not included in the bid. In addition, the cost of liability insurance for the HOTS project work force - a cost which <u>had</u> been estimated and

included in the bid submission - was running significantly higher than had been predicted. Hence, this unexpected increase to the project's overhead would also have to be accounted for through the careful management of the HOTS budget.

Thus, almost as soon as this study of the HOTS project began, the study's objectives had been overcome by events and were no longer congruent with the needs of the HOTS project manager. Of greater concern to the project manager in May 1986 than this study's objectives was his ability to retain a knowledgeable, experienced work force for the project's duration. Already during the first three months of HOTS construction the project manager had witnesed a marked decrease in the total direct work man-hours that his crews required to complete each successive HOTS. By mid May, this total had dropped to nearly one half the number of estimated direct work man-hours per site. Hence, it appeared that the experience gained by the HOTS construction crews because of the repetitive nature of the work had, itself, significantly improved the productivity of the HOTS work force.

The project manager's question in May 1986 -- more pertinent than any question raised from the study's objectives -- was this: what could be done to insure that the group of foremen, craftsmen, and helpers amassed at the HOTS project would remain with Becon at the Belridge Oil Field for the duration of the scheduled construction? This question was especially important to the HOTS project manager considering the potentially negative

impact on his workers of the extreme heat and dust during the impending months of summer.

Additionally, the HOTS project manager also raised the issure of boredom at the work place and its influence on worker retention. In other words, the project manager wondered if the repetitive nature of the HOTS construction - almost resembling a manufacturing industry's assembly line environment - would induce boredom among his workers. And, if such boredom should develop in the HOTS work force, would it lead to an increase in worker turn-over?

In research concerning the satisfactions and dissatisfactions of construction work and their relation with the productivity of construction personnel, Dr. John D. Borcherding found that the work itself - when it was well planned and permitted workers to be productive - lead directly to job satisfaction.[13] This concept was contrary to the traditional ideas of industrial psychology experts such as Frederick Herzberg who contended that just the reverse was true: greater job satisfaction at the workplace lead to greater productivity of the workers.[14] Hence, industrial psychology experts advocated the enhancement of an employee's job satisfaction through a technique known as job enrichment.[15] On the other hand, Dr. John D. Borcherding's research findings indicated that the human factors in managing construction were truly different from those of industry in general.[16] Consequently, job enrichment

was not necessarily an effective technique to directly achieve job satisfaction among construction craftsmen.[17]

1.6 Revised Objectives of the Study

The resolution of the various management concerns raised by the HOTS project manager in May 1986 boiled down to the task of determining the satisfactions and dissatisfactions of HOTS construction work, as well as the factors that effected them. Since the HOTS project represented a unique blend of the manufacturing and construction industries, it was felt that further research was warranted regarding the satisfactions and dissatisfactions of construction work. The direction of this study's focus, then, was shifted from the investigation of learning curve effects on the productivity of HOTS craftsmen toward the research of human factors in managing the HOTS construction project.

In formulating answers for the HOTS project manager's questions concerning worker retention, the opportunity existed to acquire additional data for comparison with those of Dr. John D. Borcherding's pilot study. The open shop construction craftsmen and helpers engaged in repetitive construction at the HOTS project proved to be unlike any of those included in the pilot study. Therefore, the revised objectives for this study of the human factors in managing the HOTS construction project were as follows:

- To identify the job satisfactions related to the HOTS construction.
- To identify the job dissatisfactions related to the HOTS construction.
- To identify the factors that effect these identified job satisfactions.
- To identify the factors that effect these identified job dissatisfactions.
- To recommend to the HOTS project manager ways in which to increase job satisfactions and to reduce job dissatisfactions in order to enhance the retention of the work force.

CHAPTER 2. DATA COLLECTION

2.1 Summary of Methodology

Data was collected for this study during the initial 8 months of the HOTS construction project, beginning with project mobilization in January 1986 and ending on the last work day in August 1986. Although the HOTS project's scheduled duration was 22 months, this 8-month period for data collection provided sufficient information with which to achieve the study's revised objectives. Moreover, a study period shorter than the project's intended duration was consistent with the study's overall goal: to assist the project manager in his efforts to retain for the duration of the project a knowledgeable, experienced group of foremen, craftsmen, and helpers. In other words, the HOTS project manager needed early on in the course of construction effective feedback from the results of this study. Hence, for the purposes of this study the researcher assumed the role of a consultant working with the project manager for the betterment of HOTS construction efforts, both on-going and planned.

An initial, investigative visit was made to the project site on 28 February 1986. Thereupon, one week-long visit was accomplished each month from May 1986 to August 1986. Each weeklong visit commenced with an exchange of information between the project manager and the researcher. During this exchange, the project manager conveyed the latest developments regarding construction

scheduling and project manning. Additionally, a second briefing between these two individuals was conducted upon the conclusion of each visit. All data collected by the researcher were afforded to the project manager during these briefings. More importantly, the project manager and the researcher discussed possible conclusions concerning the satisfactions and dissatisfactions of the HOTS work force. Further, they devised potential applications of their findings to the on-going management of construction activities at the project such that the retention of experienced crew members would be maximized.

As a result, the conclusions and recommendations presented in this thesis contain no surprises for the project manager. On the contrary, any information from this study that was potentially beneficial to the management of construction operations at Becon's HOTS project had long since been passed on to the project manager by the time this thesis was reduced to writing.

Various methods were utilized during this study to collect project data. In keeping with the original objectives of the study, the initial emphasis was in measuring the productivity of each work crew and evaluating the impact on worker productivity of such external factors as work methods improvement, absenteeism, accidents, weather, and personnel turnover. Consequently, the HOTS project records were examined, and information relating to worker productivity and the external factors was recorded. Furthermore, the activities of each construction crew - civil,

mechanical, electrical, and prefabrication -- were photographed using a time-lapse movie camera. This time-lapse film, then, was to be analyzed in order to devise improvements in the work methods employed at the construction site. Moreover, a delay survey was prepared and administered to the HOTS project's foremen for a 3 week period in May 1986. It was hoped that the survey results would identify work constraints other than the two already known to exist: the supply of design information and engineered mechanical equipment.

The change of the study's focus also generated a shift in the concentration of project data collection efforts. While the previously mentioned data continued to be gathered, questionnaries for all three levels of the project work force were drafted and submitted to the project manager for his review and approval in June 1986. Once approved, the questionnaires were administered through the use of one-on-one interviews between the researcher and the members of each level of the project hierarchy: the construction craftsmen and helpers, the foremen, and the managerial staff.

Work sampling was also performed by the researcher during each of the week-long visits to the project site. The activities of each work crew were observed and recorded using a standard work sheet adapted for use at the HOTS project.[18] The reason for collecting these activity samples was to obtain an overall picture of the level of activity associated with each construction crew.

Lastly, some of the most insightful information about the attitudes, satisfactions, and dissatisfactions of the HOTS work force was gained through informal conversations with personnel at all levels of the HOTS project hierachy. The views expressed by the HOTS personnel during these casual discussions on the job site were often unsolicited by the researcher. The mere initiation of conversation with crew members yielded comments which afforded the researcher a valuable awareness of the makeup of the construction crews, to include individual concerns, perceptions, frustrations, and satisfactions. Obviously, the establishment and maintenance from the study's outset of a mutual sense of respect and confidence between the researcher and the project work force was a key factor in opening this informal line of communication.

In summary, the following sources of information were tapped for data during the study of the HOTS construction project from January 1986 to August 1986:

- Project Documents
- Time-Lapse Photography
- Foremen Delay Surveys
- Questionnaires
- Work Sampling
- Informal Feedback

Each information source will now be discussed in further detail.

2.2 Project Documents

Various administrative records for the HOTS project were utilized to collect data during the course of this study. At the heart of the project's record-keeping system were the Daily Time Reports on which each HOTS foreman assigned crew man-hours to any one of seven cost codes at the close of each workday. This information was compiled by the HOTS project field staff, and then combined with the total daily man-hours recorded on the job's brass log to produce a Labor Analysis Report (LAR). The LAR served as a valuable source of project productivity data. This report was published weekly at the job site by means of a personal computer network that employed software developed for Becon Construction field management. In particular, the LAR for the HOTS Project listed the cumulative total of direct and indirect man-hours, classified by cost code, that were performed at the job site. These totals were further divided into cumulative direct and indirect man-hours, by cost code, accomplished per separate test station. Hence, it was a simple matter to extract from the LAR the total direct man-hours expended by each of the construction crews (or trades) to complete individual heavy oil test stations. These direct work man-hours per HOTS, then, were the elements of comparison in the site manager's evaluation of each crew's productivity as construction progressed.

In May 1986, the researcher was placed on the HOTS Project mailing list for the LAR as well as for the Daily Force Report: a

detailed listing by workday of manual (direct work) and nonmanual (indirect work) worker attendance, personnel hires and terminations, and project site weather. For the period covering the project's mobilization until May 1986, the file copies of Daily Force Reports were examined and the appropriate absentee, turnover, and weatner data were recorded. However, file copies were unavailable for 4 workdays in March 1986 and 1 workday in April 1986. Additionally, weather data were not recorded consistently on the Daily Force Reports. Therefore, copies of the Local Climatological Data (Monthly Summary) were obtained for the January 1986 to August 1986 time frame from the National Weather Service Office located at Kern County Airport, Bakersfield, California. These climatological data contained an accurate record of the daily temperatures and precipitation encountered on the HOTS project site. Lastly, termination and hiring information on the Daily Force Reports was verified by examining the project's cumulative Employee Log.

Also reviewed were the project's Weekly Progress Reports and the records of lost-time accidents. The progress reports provided insight to tne actual HOTS completion schedule during the first 8 months of the project's construction; whereas, the accident files complemented the project safety officer's evaluation of the nature and extent of the injuries that occurred during this same period.

In summation, the HOTS project documentation was a ready source of the following data to be analyzed in Chapter 3 of this tnesis:

- o Construction Crew Productivity
- o Worker Absenteeism
- o Personnel Turnover
- o Weather
- o Accident Rate

2.3 Time-Lapse Photography

The pnotographic recording of the activities of construction crews proves beneficial to construction managers in that a clear record is created of the work methods employed on the job site. This record, then, enables those involved in the management and execution of construction operations to review project procedures with any one of several objectives in mind. One of these objectives would be to educate laborers in the handling and repair of new equipment or in the use of new techniques. Another objective might be to train less experienced workmen to effectively accomplish an unusual or complex task. Still another purpose in viewing photographic recordings of construction activities could be to devise improved, more efficient work methods for future implementation.[19]

Current video cassette recorders (VCR) and motion picture cameras are convenient enough to facilitate the photography of construction operations for such purposes; however, the use of VCR's or movie cameras also poses two major disadvantages for the

project manager: the cost of the film and the time required to view the filmed activities. A standard 5-foot roll of super 8-mm film costs approximately $10.00 to purchase and develop. Since a 50-foot roll contains 3,600 frames and is exposed at a rate of 16 frames per second under normal motion picture recording procedures, the roll is only able to photograph 3.75 minutes of any particular construction sequence. Thus, the price of film procurement and development, alone, would exceed $150.00 per hour if super 8-mm motion picture techniques are utilized. Furthermore, whatever is the duration of the operation recorded on super 8-mm film at the standard film speed of 16 frames per second will also be the amount of time required to subsequently view the film.

This, too, is the viewing time requirement for video cassette recordings. While the least expensive video cassettes cost from $5.00 to $10.00 with no additional development expense, the recording period per cassette is still somewhat limited: 120 to 180 minutes for most video cassettes recorded at standard speed. (Recordings at speeds slower than standard speed are possible; however, these recordings possess a noticeable decrease in quality as a result of the slower recording speed.) Moreover, most video cameras are bulky to handle and require a significant power supply: either from a hand-carried battery pack or from an external 120V, 60 cycle electrical outlet.

On the other hand, the use of time-lapse (TL), photography offers distinct advantages over those recording techniques employing

super 8-mm motion pictures or video cassettes. In the TL process separate photographs of an activity are taken at a distinct time interval. Consequently, motion picture film can be made to last for relatively long periods of time, without sacrificing any quality in the photographs themselves. Moreover, no special film is required for TL photography. Instead, a TL movie camera -- merely a super 8-mm movie camera with a variable interval shutter timer -- employs standard super 8-mm film. Using a photograpnic interval of 4 seconds, (one frame exposed every 4 seconds), the 50-foot roll of super 8-mm film can last up to 4 hours, rather than the 3.75 minute duration associated with the standard interval of 16 frames exposed every second. Hence, film acquisition and development costs drop from $150.00 per hour to approximately $2.50 per hour when TL photography is substituted for normal motion picture techniques.

The economy gained in photographing a construction operation with TL procedures is also achieved when viewing the film. TL movie projectors allow the film speed to be adjusted to numerous settings. At a viewing speed of 3 frames per second, for example, a 50-foot roll of super 8-mm film can be viewed in only 20 minutes. Thus, an activity that took 4 hours to photograph can be reviewed in 1/12th that amount of time. Although only a fraction of that construction activity is captured on film exposed with TL procedures, the study of the construction operation can still prove to be extremely valuable for construction managers. In particular, viewing TL films often reveals to the observer the existence of

cyclic or repetitive trends at the job site that normally are not noticed by construction foremen or managers during their routine supervision of work activities. These trends might include events such as "work interference, customary yet ineffective work habits, minor schedule changes, or operational delays,"[20] Lastly, in comparison to most video cassette recorders and players, TL movie cameras and projectors are more easily handled and operated.

Because one of the original objectives of the HOTS project study was to devise work methods improvements for the construction crews, the photographic recording of various project activities was begun in May 1986. The following TL photographic equipment maintained by the Architectural Engineering Department at the University of Texas at Austin was utilized:

- o Minolta XL-601 Super 8 Camera
- o Kodak Super 8 Color Movie Film (Type G, ASA 160 and Type A, ASA 40)
- o Photographic Tripod

Even after it became clear that the study's original objectives had been overcome by events, the HOTS project manager encouraged the continued TL photography of his construction crews in order to formally preserve for Becon Construction a record of the various craft operations that comprise the construction of a heavy oil test station. Additionally, the films of each activity were eventually shown to the respective construction crews in July

and August 1986 as a team building effort to be discussed further in Section 3.5.

A total of twenty-two 50-foot rolls of super 8-mm film were exposed using TL procedures during the researcher's four week-long visits to the HOTS project site from May to August 1986, see Table 3. Those activities photographed consisted of the major operations involved in the completion of a HOTS. The interval selected for the TL camera's shutter timer during all filmings was 4 seconds. This interval was subject to minor deviation, however, since the timing adjustment on the camera was accomplished by synchronizing the sound of the shutter opening/closing with the passage of time as registered on a digital wrist watch.

In the HOTS project prefabrication and storage yard area the TL camera was mounted on the tripod, then located on the top of the painter's 10-foot high tool trailer, see Figure 7. At the individual heavy oil test stations, the TL camera was attached to one of the light poles with an improvised clamping device that was fabricated by one of the pipefitters in the prefabrication crew. The TL camera was elevated approximately 20 feet on the light pole, see Figure 8. A man basket attachment for the project's cherry picker was placed into service for positioning and retrieving the TL movie camera when it was mounted on a light pole. At those HOTS where light poles had not yet been positioned, the TL camera was mounted on the tripod and situated in the bed of a pickup truck parked near the activity being photographed. This position proved

TABLE 3

Film Roll	Date	AM or PM	Site	Film Type	Crew	Activities	Comments
1	13 May 1986	AM	154	A	Electrical	Aboveground Electrical	Overexposed
2	13 May 1986	PM	154	A	Electrical	Aboveground Electrical	Overexposed
3	14 May 1986	AM	152	A	Mechanical	Aboveground Pipe	Overexposed
4	14 May 1986	PM	152	A	Mechanical	Aboveground Pipe	Overexposed
5	15 May 1986	AM	Yard	A	Prefabrication	Cut, Fit, Weld Pipe	Overexposed
6	16 May 1986	AM	159	A	Civil	Place Foundation	Overexposed
7	16 June 1986	PM	Yard	A	Prefabrication	Cut, Fit, Weld Pipe	Backlight Feature Employed
8	17 June 1986	AM	163	G	Civil	Form Foundation	
9	17 June 1986	PM	163	G	Civil	Form Foundation	
10	18 June 1986	AM	198	G	Mechanical	Aboveground Pipe	
11	18 June 1986	PM	198	G	Mechanical	Aboveground Pipe	
12	19 June 1986	AM	Yard	A	Prefabrication	Cut, Fit, Weld Pipe	Backlight Feature Employed
13	19 June 1986	PM	Yard	A	Prefabrication	Cut, Fit, Weld Pipe	Backlight Feature Employed

TABLE 3

HUTS Project Activities Photographed in Time-Lapse

TABLE 3 (Continued)

HOTS Project Activities Photographed in Time-Lapse

Table 3

Continued

Film Roll	Date	AM or PM	Site	Film Type	Crew	Activities	Comments
14	14 July 1986	AM	102	G	Electrical	Aboveground Electrical	Backlight Feature Employed
15	14 July 1986	PM	102	G	Electrical	Aboveground Electrical	Backlight Feature Employed
16	15 July 1986	AM	Yard	A	Prefabrication	Cut, Fit, Weld Pipe	Backlight Feature Employed
17	16 July 1986	AM	Yard	A	Yard	Lift, Load Pipe	
			107			Set Engr'd Equip.	
			Yard			Sand Blast Pipe	
18	17 July 1986	AM	Yard	G	Yard	Lift, Load Engr'd Equip.	
					Yard	Painting	
					Yard	Lift, Load Pipe	
					Prefabrication	Cut, Fit, Weld Pipe	Backlight Feature Employed
19	18 July 1986	PM	102	A	Civil	Final Grading	
20	12 Aug 1986	AM	103	G	Yard	Painting	
			186			Set Engr'd Equip.	
21	12 Aug 1986	PM	186	A	Yard	Lift, Load Pipe	
	13 Aug 1986	AM				Set Engr'd Equip.	
22	13 Aug 1986	PM	186	A	Mechanical	Aboveground Pipe	

to be the poorest from which to photograph of the three discussed, because of the camera's relatively low elevation when in the truck bed; objects in the foreground of the field of view tended to obscure activities in the background when the camera was this low.

As noted in the comments section of Table 3, the first 6 rolls of TL film were overexposed and, thereby, not viewable. Each of these rolls was exposed during the May visit to the HOTS project site. As it turned out, the camera in use during that visit possessed a malfunctioning light meter. This camera was replaced with one that was fully functional; no further mechanical problems were encountered with the TL camera during the researcher's remaining 3 week-long visits to the project.

Also of note was the fact that photographing the shaded prefabrication operation -- situated under a temporary overhead cover -- from the top of the painter's tool trailer -- a spot that afforded absolutely no shade -- was best done by use of the backlight feature on the Minolta XL-601 movie camera. The employment of this feature provided greater exposure to the shaded prefabrication operation when it was filmed from a distant location exposed to bright sunlight. Consequently, the films of the shadowy prefabrication activities that were photographed in this manner exhibited greater clarity and increased definition than those films of shaded activities that were recorded without the backlight feature.

Lastly, the Kodak film, type A, ASA 40, produced a consistently better quality film product throughout the study than

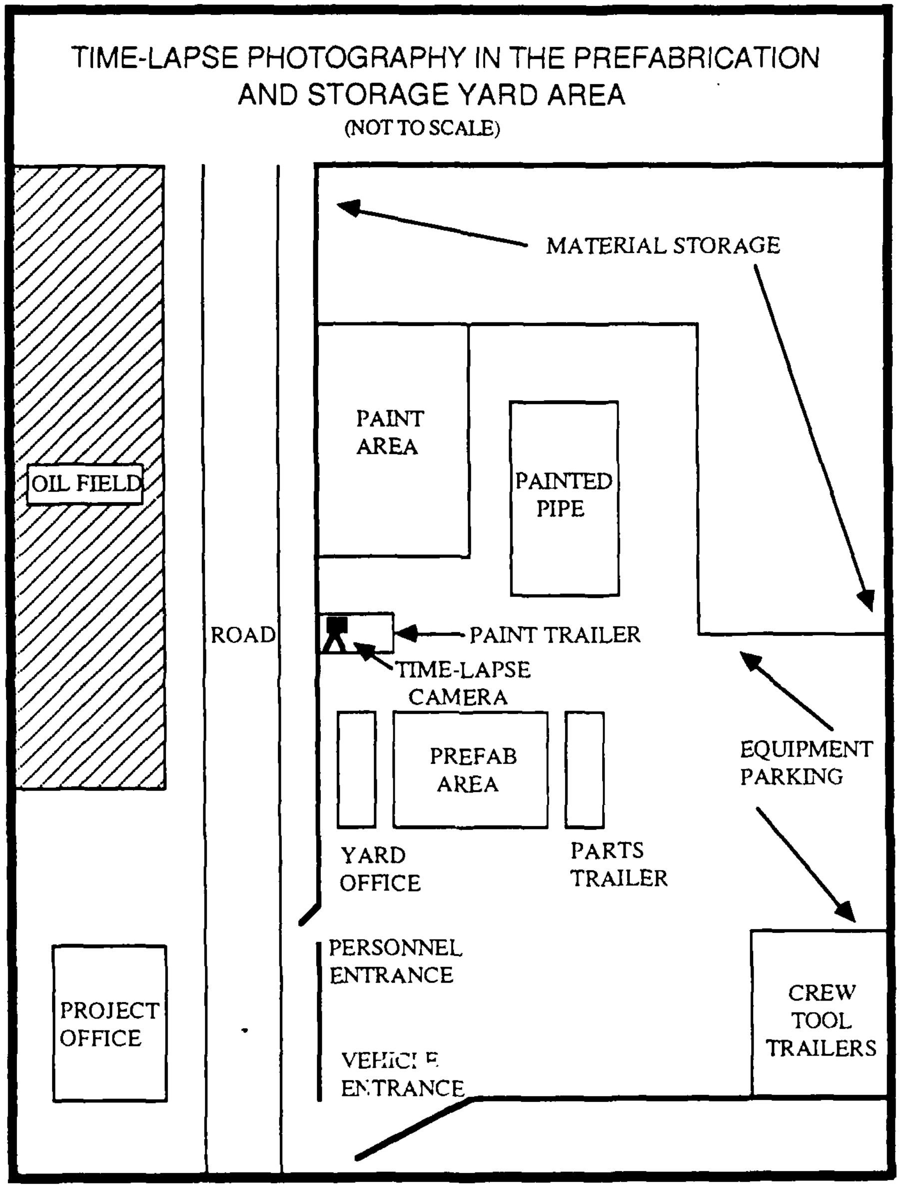


FIGURE 7

Time-Lapse Photography in Prefabrication and Storge Yard Area

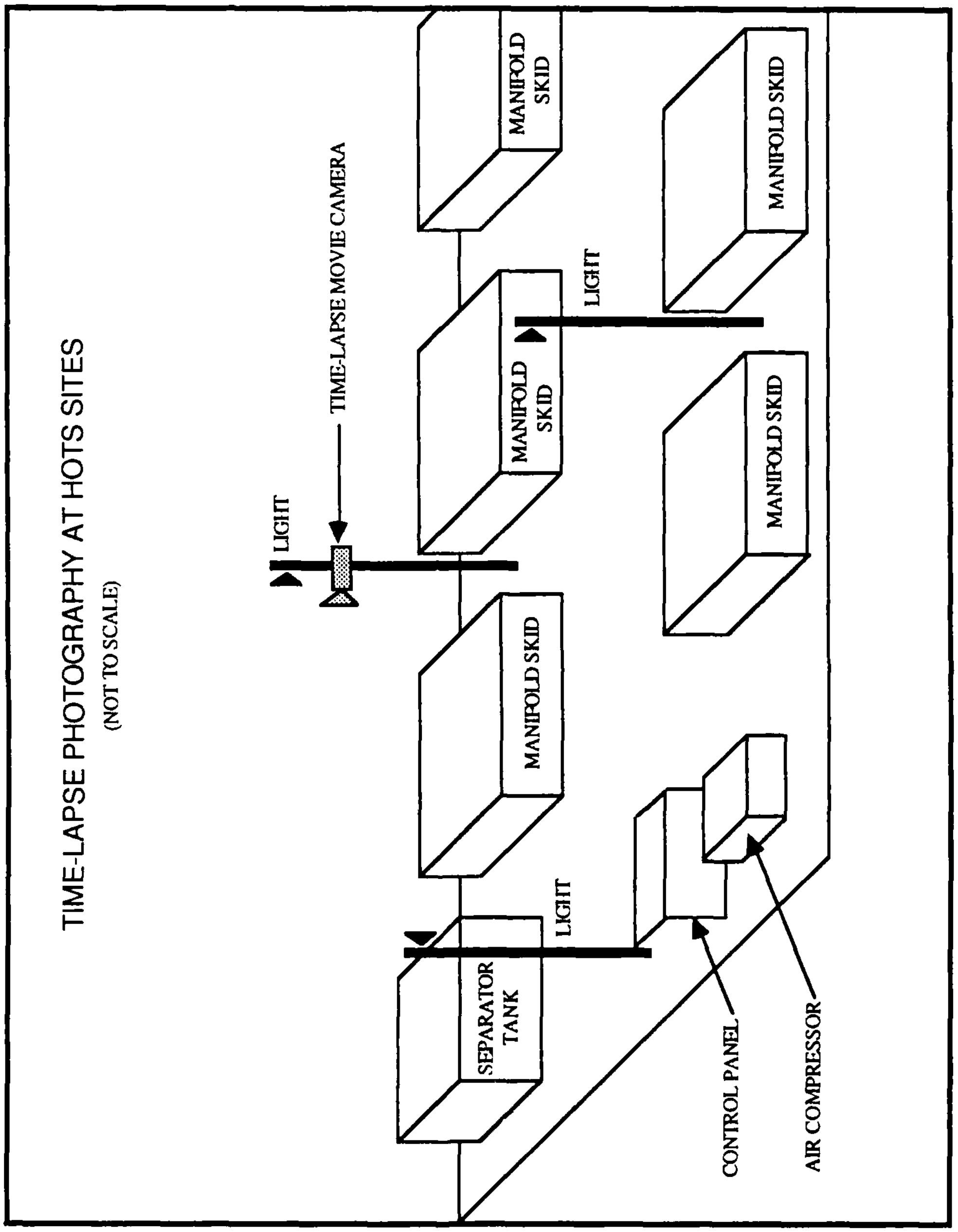


FIGURE 8

Time-Lapse Photography at HOTS Sites

did the Kodak film, type G, ASA 160. The activities filmed at the HOTS project were all located outdoors and were photographed using natural sunlight. As a result, the type G film -- more sensitive to sunlight than type A film -- routinely exhibited a grainy, washed-out appearance once developed. Type A film is recommended for future outdoor TL photographic operations.

2.4 Foreman Delay Survey

The surveying of construction foremen to identify the nature and extent of delays experienced by their crew members proved to be an effective data collection technique in the Construction Industry Institute's (CII) pilot study of the effect of scheduled overtime and shift schedule on construction craft productivity in 1984.[21] Specifically, a delay survey afforded the foremen at the projects under investigation an opportunity to record adjustments to daily crew hours logged at the job site in order to reflect an accurate amount of actual "worked manhours."[22] Indeed, total daily available crew hours might require modifications to account for manhours lost or gained at the work place as a result of any of the following factors:

- o Delays imposed by slow material deliveries, equipment nonavailability, tool shortages, inspections, lack of design information, or inaccessibility of the work area.

- o Work efforts to execute field changes, demolition tasks, tie-ins, or other activities under supervision of a foreman, but, which do not result in reportable quantities of completed work.[23]

As mentioned in Section 1.4, the HOTS project manager's ability to manage the efforts of his construction crews was constrained by two known factors: the incremental supply of design information and engineered mechanical equipment. But, did there exist other constrained support systems at the HOTS Project -- those operating at less than an optimum utilization -- which were unknown to the site manager? And, if such constrained support systems did exist, what were the causes of these as yet unidentified constraints? In an attempt to answer these questions, the foreman delay survey (FDS) from the CII pilot study was adapted in May 1986 for use at the HOTS Project, see Figures 9 & 10.

There were two sides to the FDS. The front side provided sufficient information for each foreman to complete the survey. In particular, the purpose of the FDS was addressed on the front side of the form along with instructions for filling in the heading and columnar portions of the form's worksheet: the back side of the FDS. These instructions are clearly presented in Figure 9 and will not be repeated here.

The information printed on the front side of the FDS also solicited foremen to specifically address eight different areas causing possible delays, as well as to identify other constraints encountered on the job site and not listed on the worksheet. Once again, these areas are clearly indicated in Figures 9 and 10 for review.

FOREMAN DELAY SURVEY INFORMATION

1. Purpose

The University of Texas At Austin, in cooperation with Becon, is conducting a study of productivity at the HOTS Project. The quantities and hours to be used in the actual calculations of productivity will be taken from the Foreman's Daily Time Report and from this Foreman Delay Survey. The foreman of each crew fills out this form daily. Please record on the form those items which caused delays to your crew.

2. General:

Turn this form in daily with your Daily Time Report. If your crew does not have any delays for a particular day, note that on the form and turn it in. Data collection for this study will start as soon as possible, and it will be collected until further notice. This survey is a critical part of the overall study. Your cooperation in carefully completing this form will greatly assist us in obtaining the most accurate possible data.

3. Heading:

Fill in the heading with the date, your craft, your name, and the number of your crew physically present on this date. Do not count those personnel assigned but absent. If you have someone from another crew working with your people, include him in the count. Do not count equipment operators, inspectors, or support personnel.

4. Problems Causing Delays:

There are eight reasons given for possible delays listed in the first column. You are asked to specifically address the areas of materials, tool availability, equipment availability, inspections, design/engineering, instructions and permits. If any other items come up during the day that result in a delay, they should be recorded under "other" at the bottom of the page and explained. There is also a place for indicating if the crew was performing rework.

5. Total Manhours Lost:

Under "number of hours" write the length of the delay. Under "number of men" write the number of people affected by the delay. If an item did not cause a delay during a particular day, leave it blank. Record minutes as fractions of an hour. Obtain total manhours lost by multiplying the total time lost by the number of people affected.

Example: 3 men wait 45 minutes for a special tool. 45 minutes = 3/4 of an hour. (3 men) x (.75 hours) = 2.25 total manhours lost.

6. Comments:

Record here the specific reasons for each delay. If more space is needed, use another line. Be as specific as possible.

FIGURE 9

Foreman Delay Survey (Front Side)

RECON CONSTRUCTION COMPANY, INC.
SHELL CALIFORNIA PRODUCTION, INC.
HEAVY OIL TEST STATIONS
BAKERSFIELD CALIFORNIA
JOB 1264

FOREMAN DELAY SURVEY

CRAFT: ____________ DATE: ____________

FOREMAN: ____________ # IN CREW PRESENT: ____________

	PROBLEMS CAUSING DELAYS	# OF HOURS X # OF MEN = MANHOURS			COMMENTS
1.	MATERIALS				
2.	TOOLS				
3.	CONSTRUCTION EQUIPMENT				
4.	INSTRUCTIONS				
5.	ENGINEERING INFORMATION				
6.	INSPECTION				
7.	ACCESS TO WORK SPACE				
8.	PERMITS				
9.	REWORK:				
	A) ENGINEERING CHANGE/ERROR				
	B) FIELD CHANGE/ERROR				
	C) DAMAGE BY OTHERS				
10.	OTHER:				
	A)				
	B)				
	C)				

FIGURE 10

Foreman Delay Survey (Back Side)

After the site manager examined and approved the FDS as modified from the version in the CII pilot study for use at the HOTS Project, sufficient blank copies were produced to support the survey's implementation for a minimum of 4 weeks. The blank forms were left with the project superintendent at the close of business on 16 May 1986. Prior to departing the project site on 16 May, the researcher explained to the superintendent the procedures and frequency for completing the FDS's. As it turned out, the HOTS project superintendent had had experience with a similar survey at a previous Becon Construction Company project. Hence, it was left for the project superintendent to initiate the daily use of the FDS by the HOTS construction foremen. Subsequently, the completed FDS's were reviewed by the site manager, then forwarded to the researcher at the University of Texas at Austin. On 16 June 1986, the start of the researcher's second week-long project visit, both the HOTS site manager and the researcher agreed to discontinue the implementation of the FDS's on the project. In short, the survey results from 19 May to 13 June 1986 revealed no additional, significantly constraining factors impacting on the execution of construction operations at the HOTS Project. These results will be discussed further in Section 3.3.

2.5 Questionnaires

As noted in Section 1.6, the focus of the research effort at the HOTS project shifted abruptly in May 1986 from the effects

of the learning curve phenomenon on productivity to the identification and relation of job satisfactions and dissatisfactions to worker retention. Just as in Dr. John D. Borcherding's pilot study of construction work relationships, questionnaires administered by the researcher to the HOTS project personnel served as the primary means of collecting data for this study.[24] In fact, the questionnaries utilized at the HOTS project were merely adaptations of those used in the plot study.[25] Accordingly, three separate questionnaires were employed on the HOTS job to correspond with the different organizational levels of tne project: helpers and journeymen; foremen; superintendent and site manager. The interview questions as adapted for the HOTS construction personnel are listed in Appendix I.

Unlike the pilot study, the format of the questionnaires administered at the HOTS construction project did not come under tne close scrutiny of union officials.[26] Instead, draft interview questions were submittd to the HOTS project manager on 16 June 1986. Making a few slight wording modifications, the site manager granted his approval of the questionnaires shortly thereafter. At his request, the group of individuals to be interviewed was expanded to include the following members of his project management staff:

- o Safety/Procurement Manager
- o Electrical Engineer
- o Office Manager
- o Field Engineer

In announcing the interview program to his foremen and to the superintendent, the project manager stated that participation by HOTS project personnel was highly encouraged; yet, at the same time, their participation would be strictly voluntary. The majority of the questionnaires at the HOTS project were completed from 17 to 20 June 1986. Additional interviews were performed, as needed, in July and August 1986 for those construction crew members who had been hired by Becon Construction at the HOTS job since the completion of the previous month's questionnaires. A total of 41 questionnaires were administered at the HOTS project site form June to August 1986. A summary of this total according to organizational levels is depicted in Table 4.

Level	Craft					
	Carpenter	Pipe-fitter	Welder	Operator	Painter	Electri-cian
Journeymen	2	1	3	-	1	1
Helper	6	4	-	3	2	7
Foreman	1	2	-	1	-	1

Misc: Site Manager; Superintendent; Officer Manager; Electrical Engineer; Field Engineer; Safety Procurement Manager.

Table 4

Summary of HOTS Project Questionnaires

The HOTS project work force was small in comparison to the manning levels of the projects in Dr. John D. Borcherding's

pilot study.[27] Hence, it was a relatively simple matter to solicit interviews from all of Becon's craftsmen and foremen at the HOTS project. As a result, the researcher at the HOTS job did not have to settle for only a representative sampling of interviews from a large worker population, as was the case in the pilot study.[28] Furthermore, all questionnaires at the HOTS project were administered individually, as opposed to the pilot study's technique of performing group interviews for those at the lowest organizational level.[29] Also unlike the pilot study, the HOTS construction crew foremen possessed sufficient flexibility in their daily routine so as to allow their participation in the interviews at the job site. Thus, it was not necessary to conduct any home interviews of HOTS project supervisors, in contrast to the pilot study.[30]

The interviews were accomplished at or near to the assigned work place of each respondent. Interview locations were selected which offered the interviewee and the researcher privacy, shade, and a place to sit down. These locations included spots such as the foreman's pickup truck, the crew tool room, or an empty office in the project administration trailer. No time limit was established for any of the questionnaires, which were administered verbally. Comments made by individual respondents were recorded by the researcher on a preprinted blank questionnaire form.

Every interview began by the researcher explaining to the respondent that the purpose of the questionnaire was to aid the HOTS project manager in identifying how the HOTS construction

satisfied and dissatisfied the project work force. Further, it was explained that the results from the questionnaires were to be examined to determine how to maximize the retention of project personnel for the duration of the scheduled HOTS construction. Interviewees were also informed that their names would not be annotated on the blank forms used to record responses to the questions. It was additionally noted that only two individuals were to review these recorded responses: the researcher and the site manager. In other words, crew foremen and the project superintendent would not be afforded the opportunity to view the responses of any of their subordinates. During the researcher's opening comments in each interview, the respondent's age was solicited and recorded on the questionnaire form. Lastly, each individual who participated in the questionnaire program was reminded from the outset of the interview that participation was voluntary. (As it turned out, only one individual at the HOTS project -- a journeyman -- elected not to be interviewed; all others solicited to answer the questionnaires did so.)

As in the pilot study, respondents at the HOTS project were encouraged to stray from the topic of interest when answering questions, if they were discussing personal work relationships at that moment.[31] Doubtless, this interview procedure served to preserve potentially important thoughts of those interviewed at the risk of altering the structure of the interviews. The execution of interviews at the HOTS project followed no hierarchical progression,

as it did in the pilot study.[32] Rather, the HOTS project questionnaires were conducted in an order and at scheduled times that were convenient to both the respondents and their supervisors.

Also of significance to the interview process at the HOTS construction project was the rapport that developed between the researcher and the project personnel starting during the researcher's first week-long visit in May 1986. By the time that the interviews were begun at the HOTS project the following month, the researcher knew the first names of all project prsonnel. In like manner, workers at all levels of the HOTS project hierarchy had spoken informally with the researcher on at least one occasion prior to the commencement of the interviews in June 1986. Consequently, it was felt that the familiarity that existed between the researcher and those interviewed at the HOTS project contributed to the breakdown of communication barriers during the interview process itself.

Accordingly, the interviews took place in a relaxed atmosphere which facilitated a free exchange between the researcher and each respondent concerning the attitudes, values, and beliefs of the HOTS work force. Although such exchanges might be considered to have contaminated the data recorded during the interviews, statistical measurement was not of primary importance in this study. As was true in Dr. John D. Borcherding's pilot study, the purpose of performing the questionnaries was qualitative in nature:[33] to gain an understanding of the satisfactions and dissatisfactions of the HOTS construction personnel.

2.6 Work Sampling

Another useful data collection technique involves the recording of random observations of construction workers as they perform their tasks at the job site. These observations are classified when recorded into one of numerous categories such as direct work, waiting, travelling, break, personal time, late start/early quit, receiving instructions, or obtaining tools or materials. Subsequently, these quantified observations are studied and inferences are drawn about the level of activity of the construction workers as a whole. This ability to draw conclusions about the total worker population based on the study of sample observations from that population is a well established statistical principle.[34]

Work sampling, as this data collection technique is termed, is readily applied to the construction industry. However, it is important to distinguish between activity and productivity as they relate to work sampling. The results of work sampling are not indicative of the level of productivity at a construction project. Doubtless, construction workers busily engaged in work related tasks may not necessarily be productive laborers. Instead, the study of representative work samples from a large work force reveals trends in the way construction craftsmen spend their time on the job site. Such information can serve as a tool for managers to identify potential problem areas in the construction process.

It should be obvious that the larger the number of random observations that are made, the more reliable will be any conclusions drawn from such observations. Hence, the dependability or confidence limit of any inferences about the total worker population that are drawn from random activity samples is a function of the number of samples taken. In the construction industry it is generally accepted that a confidence limit of 95 percent yields a good indication of how the members of a construction operation spend their time.[35] In other words, a 95 percent confidence limit implies that any inferences about a work force as a whole that are based on representative samples can be relied upon 95 percent of the time to be true. To achieve such a confidence limit, the minimum sample size is 384.[36]

When observing construction laborers, the following general rules apply to the work sampling process:

- A sample shall contain no less than 384 observations.
- Every worker must have the same chance of being observed at any time.
- Observations must have no sequential relationship.
- The classification of observations must be accomplished the instant that a worker is first viewed.
- The observer must not alter the basic work environment while sampling worker activity.[37]

Despite these rules, various sources of error still exist when performing work sampling. Statistical sampling error can be predicted, and then controlled through the number of samples

collected. Errors resulting from the personal bias of the observer are not so easily accounted for. Moreover, it is a very real possibility that an observer's attitudes or beliefs about construction workers will influence the classifications assigned to work samples. For example, if an observer feels that craftsmen are generally lazy, this observer may be inclined to classify "waiting for tools" as "break time," "personal time," or "early quit." At the same time, the gathering of work sampling data is often tedious and fatiguing; a tired observer might be more apt to commit errors when recording observations.[38]

Procedural errors in the collection of work samples may also occur. Such errors could include the failure of an observer to notice all the workers at a particular location on the job site. Inclement weather might hinder an observer's efforts to accurately and precisely record and classify observations. The classification given to various forms of activity at the work place may vary among observers -- that is, when more than one observer is utilized -- thus leading to inconsistencies in the data. Lastly, the workers' activities themselves may undergo change merely because of the fact that they are being observed and recorded. Accordingly, a conspicuous observer may influence construction craftsmen to alter their behavior. For instance, crew members may make a special effort to appear busy when a work sampling observer is in view.[39]

Yet, in spite of these sources of error, work sampling retains several positive features that make it an attractive data

collection technique in the construction industry. Work sampling can provide a statistically reliable description of how laborers spend their time on the job site. This description is easily understood and relatively inexpensive to obtain. Observers in the work sampling process need possess no special training or experience. Finally, work sampling is very simple to apply at any construction project and with any size work force.[40]

There exist many variations in the actual method to collect work samples at construction projects. One such variation is termed a "five minute rating,"[41] so named because the period of observation is no shorter than five minutes. Five minute ratings are a quick, less exact form of work sampling. The ratings are best suited for crews, rather than for an entire project work force. In addition, classifications given to observations are generally quite simple: either "work" or "no work." A rule of thumb in performing a five minute rating is to observe and record the activity of individual crew members once every minute for a specified period. The length of this rating period, in minutes, is usually equal to the number of crew members being observed. Normally, five minute ratings are performed four times daily: twice in the morning and twice in the afternoon.[42]

It was this basic five minute rating format that was utilized at the HOTS construction project to collect activity samples from each of four work crews. However, certain modifications were made to the five minute rating technique in order to attain a

95 percent confidence limit for the samples from each crew. Furthermore, one of three classifications were used for all observations performed at the HOTS project:

- o Effective Work - The actual process of adding to the unit being constructed. This could include necessary disassembly of a unit to be modified, and required movements in the immediate area of the work being done.

- o Contributory Work - That work not directly adding to, but (through associated processes) essential to finishing the unit. This could include handling material at the work station, cleanup, personal time, receiving instruction, reading plans, waiting when some other member of a balanced crew is doing productive work, and necessary movement within (say) a radius of 35 feet of the individual's work site.

- o Ineffective Work - Doing nothing or doing something that is in no way necessary to complete the end product. This might involve such items as walking empty-handed, moving materials or self outside a radius of 35 feet from the work site, activities that would be classed as effective or contributory work but done with the wrong procedure or tool, or rework of a job done wrong in the first place.[43]

A sampling form for use at the HOTS project was adapted from a standard five minute rating worksheet[44] The front and back sides of the HOTS crew sampling form are presented in Figures 11 and 12, respectively. The phrase "crew sampling" was selected since all the observations to be recorded on each blank form would be crew specific. Observations of each of the four HOTS construction crews were made at random during each week-long project visit from June to August 1986. A summary of crew samples collected at the HOTS project is listed in Table 5. The results of these samples will be presented in Section 3.2.

BECON CONSTRUCTION COMPANY, INC.
SHELL CALIFORNIA PRODUCTION, INC.
HEAVY OIL TEST STATIONS
BAKERSFIELD, CALIFORNIA
JOB 1264

DEFINITIONS

Effective work--the actual process of adding to the unit being constructed. This could include necessary disassembly of a unit to be modified, and required movements in the immediate area of the work being done.

Essential contributory work--that work not directly adding to, but (through associated processes) essential to finishing the unit. This could include handling material at the work station, cleanup, personal time, receiving instruction, reading plans, waiting when some other member of a balanced crew is doing productive work, and necesary movement within (say) a radius of 35 feet of the individual's work site.

The difference between activities that are contributory and those that are nonessential is sometimes small and must be carefully defined. For example, drinking water should be considered a personal allowance but drinking soft drinks should not be. Waiting while some other member of a crew is working would require stricter interpretation. The person rated as contributory would have to be on the same crew, handling the same material; the crew must be properly sized for the task; and there must be absolutely nothing the man could do to use his time. Only one man on the crew could so qualify.

Ineffective work--doing nothing or doing something that is in no way necessary to complete the end product. This might involve such items as walking empty-handed, moving materials or self outside a radius of 35 feet from the work site, activities that would be classed as effective or contributory work but done with the wrong procedure or tool, or rework of a job done wrong in the first place.

Examples

Effective work--painting a wall, placing bricks, attaching a valve to a pipe, nailing boards on a wall, hauling material from an excavation, or movement within 10 feet of the individual's work position. Other items such as mixing mortar for bricks, threading a piece of pipe, and cutting boards before nailing can be classed as effective work, as long as they are done effectively.

Essential contributory work--building a scaffold to serve as a work platform, measuring a piece of pipe or placing it in a machine preparatory to cutting and threading, returning an empty truck to be filled, or movement within the area extending from (say) 10 feet to 35 feet of the individual's work position.

Ineffective work--walking empty-handed or carrying anything more than 35 feet from the work position, coffee break, waiting for a truck, riding on a truck, correcting an error, going back to shop for a tool or a part, or discussing last night's ball game.

FIGURE 11

Crew Sampling Form (Front Side)

CREW SAMPLING

Weather: ______________________ Date: __________
Site:
Foreman: ______________
Activities ____________________________________

Time									Comments

Total Man Units: ___ Effective: ___ Effectiveness: ___

FIGURE 12

Crew Sampling Form (Back Side)

Date	Crew	Total Daily Observations	Total Daily Observation Periods
16 June 1986	Prefabrication	189	3
17 June 1986	Civil	303	5
18 June 1986	Mechanical	666	6
20 June 1986	Electrical	90	1
20 June 1986	Prefabrication	84	1
14 July 1986	Electrical	357	5
15 July 1986	Prefabrication	336	4
16 July 1986	Prefabrication	166	2
17 July 1986	Prefabrication	242	3
18 July 1986	Civil	236	3
13 August 1986	Mechanical	328	4

Table 5

Summary of HOTS Project Crew Sampling

Also of note is the fact that the same observer -- the HOTS project researcher -- performed all of the crew samples throughout the course of the study. Although this use of a single observer did not necessarily eliminate the possibility of procedural errors in the data collection process, this practice did enhance the consistency of the samples' classifications. Additionally, the researcher performed the crew sampling in a relatively unbiased manner, possessing no preconceived notions about the level of activity of any of the HOTS crew members.

Similarly, it was felt that the researcher's performance of crew sampling observations went virtually unnoticed by the HOTS construction crew members. Having made informal contact early on in the study with most of the HOTS personnel, the researcher was a known figure at the project. In time, the tendency was for the

researcher to blend in easily at each HOTS site. As a result, crew samples were a rather simple matter to accomplish from a single observation point at each HOTS; there was no need for the researcher to move among the workers in order to collect crew samples, since the HOTS sites were small enough to permit the review of all crew members' activities from one location.

The HOTS crew sampling form was easily completed. Copies of completed forms were submitted to the HOTS project manager at the close of each work day in which crew sampling was executed.

An example of typical observations for the mechanical crew is presented in Figure 13. The titles of the crew members were listed across the top of the worksheet. Then, a block of time was entered by minute intervals in the left-most column. The actual entries on the form consisted of an "E" for effective work, a "C" for contributory work, and and "I" for ineffective work.

Observations were made once a minute for a period up to 21 minutes in length. Considering that the average crew size was less than 10 members, a 21 minute observation period was somewhat longer than the length dictated by five minute rating guidelines, (one minute of duration for every crew member). Still, this modification to the five minute rating technique was instituted in order to increase the sample size per crew during each observation period. Consequently, a confidence limit of 95 percent was achieved for the data from each crew that was studied from June to August 1986.

CREW SAMPLING

Weather: SUNNY / WARM Date: 18 JUNE 1986
Site: 198
Foreman: WALLY PORTER
Activities FIT/WELD PIPE

Time	FOREMAN	JOURNEYMAN	HELPER	HELPER	HELPER	WELDER			Comments
1050	C	E	E	E	I	E			
1051	C	E	E	E	I	E			
1052	C	E	E	E	I	E			
1053	E	E	E	E	E	I			
1054	E	C	E	E	I	E			
1055	E	E	E	E	I	E			
1056	E	C	E	C	I	C			
1057	E	I	I	I	I	E			
1058	E	C	E	E	I	E			
1059	C	I	E	E	E	I			
1100	E	E	E	C	I	I			
1101	E	I	E	I	I	I			
1102	E	I	E	I	I	I			
1103	E	C	E	C	C	I			
1104	I	I	E	E	E	I			
1105	I	I	E	E	E	I			
1106	I	I	E	E	C	I			
1107	E	I	E	E	E	I			
1108	E	I	E	E	E	I			
1109	I	E	E	E	C	I			
1110	I	E	E	E	I	I			

Total Man Units: 126 Effective: 68 Effectiveness: 54%

FIGURE 13

Example of Crew Sampling Data

The number of crew sampling forms completed per day was solely dependent on the opportunities for observation that were available to the researcher during each week-long visit. The basic intent of the researcher was to maximize the number of crew samples performed during each visit. This maximization was considered essential to the data collection process since the total on-project time for the researcher was limited to only four weeks from May to August 1986.

It should also be pointed out that the mechanical crew was lead by a "working" foreman; therefore, observations of this foreman that occurred during the sampling of his crew were included as entries on the crew sampling form. On the other hand, the other crew foremen at the HOTS project served mainly in a supervisory capacity; their activities as noted during crew sampling were excluded from entry on crew sampling work sheets.

2.7 Informal Feedback

The collection of informal feedback from individual workers comprised a significant portion of each day that the researcher spent at the HOTS construction project in California. While observing construction activities at the separate HOTS sites and in the prefabrication area, the researcher availed himself of countless opportunities to initiate informal conversations with journeymen, helpers, and foremen, alike. Many of the remarks made to the researcher during these informal conversations were unsolicited.

In other words, the comments were not made in reply to specific questions posed by the researcher. Instead, the researcher's standard conversation-initiating query, "How's it going?", often yielded from HOTS construction personnel a lengthly discourse concerning the project environment, the worker's attitudes and frustrations, or the latest rumors. As a result of these countless informal discussions, the researcher gained a greater understanding of the composition and character of the HOTS work force, as well as an increased appreciation for the on-site working environment and the concerns of the individual foremen, journeymen, and helpers.

To be sure, more than just the researcher benefitted from these interchanges between the researcher and the construction crew members. For the HOTS project manager, the information gained by the researcher during such exchanges served as feedback regarding the implementation of corporate policies and the effectiveness of his formal project communication channels. On more than one occasion, concerns that were voiced by crew members to the project researcher had been previously identified by the site manager and resolved through appropriate action. In such cases, the complaints informally offered by workers at the lowest project levels proved to be extremely valuable to the project manager. Accordingly, the site manager acted on this informal feedback provided him by the researcher to identify whether or not the formal lines of communication at the project had been effective in disseminating to the workers the managerial actions taken to rectify the voiced

complaints. Moreover, if management's initiatives had, in fact, been well communicated to the workers, then the feedback gathered informally by the researcher seemed to indicate to the site manager that the implemented actions, themselves, were not successful in resolving the worker irritants.

The foreman, journeymen, and helpers at the HOTS construction project also profited from the temporary installment on the project site of an informal line of communication. In his introduction of the researcher to the HOTS project work force in May 1986, the project manager clearly stated that members of the construction crews and project staff, alike, should feel free to talk to the researcher about any work-related issue. Further, he noted that no one would lose their job as a result of remarks made to the researcher. In addition, the site manager portrayed the researcher's role to project personnel as that of an informal consultant, non-threatening to the job security of Becon employees. Finally, the project manager conveyed to project personnel his extremely supportive attitude regarding the researcher's scheduled efforts to study the HOTS construction.

As a result, the broader implication from the site manager's remarks seemed to be that the researcher represented a direct communication line to project management for the work force. Consequently, in some situations it was readily apparent to the researcher that the comments made to him by construction crew

members or foremen were intended, in reality, for the site manager's ears. Hence some members of the lower levels of the HOTS project hierarchy took advantage of this resource to express informally to management both their praise and their criticism of project-related issues.

However, the fact that some workers utilized the researcher as an informal line of communication is not reported here to imply that communications at the HOTS project were ineffective. On the contrary, communications on the job site -- upward, downward, and horizontal -- were generally quite effective. Indeed, project management's total support of the researcher in his efforts to solicit informal feedback from among the work force attested to the importance placed on effective project communications by the site manager.

One final facet of the HOTS study benefitted from the conduct of casual conversations between the researcher and project personnel. The mere act of conversing with the HOTS crew and staff members gave the researcher a tremendous opportunity to earn their acceptance early in the study. Starting during his first week-long project visit, the researcher learned the names and some personal history of each construction crew member. In the process of learning about the HOTS work force, the researcher was also able to disseminate to the crew members exactly what he was studying at the HOTS project site and why. Furthermore, because the researcher was an active duty member of the United States Army, he was able to develop

ties with numerous HOTS personnel, in particular, who had previously served in the United States Armed Forces.

Therefore, by the start of the second week-long project visit -- when the implementation of questionnaires began -- the researcher had planted himself on solid ground, so to speak, in terms of his credibility with the HOTS work force. It was felt that the mutual respect and confidence which developed between the researcher and the construction personnel were a direct result of the informal conversations carried on between them. Ultimately, it could be concluded that the work force's rapid acceptance of the researcher facilitated the meaningful exchange of information during the formal interview sessions. In terms of the revised objectives of the HOTS study, then, the researcher's credibility -- gained through the process of soliciting informal feedback from project personnel -- contributed to the collection of valuable qualitative data for use in identifying what about the HOTS construction project satisfied and dissatisfied the construction personnel.

CHAPTER 3. ANALYSIS OF DATA

3.1 Summary of Methodology

Because of the revision of the HOTS project study objectives midway during the course of the research, the direction of the efforts to collect data at the project site developed into an almost shotgun-like approach. Although the amassed project data were relatively broad in scope, the analysis of this data was accomplished with a narrow focus, keeping in mind the qualitative nature of the revised objectives for the project's study. As a result, the analyses of the quantitative project data presented in this thesis constitute more an informational reporting of results than actual statistical analyses of collected data. In particular, no attempt was made to curve-fit the observed learning curve phenomenon as recorded in the project productivity data. Neither was there made any effort to identify external factors that influenced this recorded learning curve phenomenon. In fact, the reason that the quantitative data is reported, at all, is to present as accurate a portrayal as possible of the HOTS project environment and work force from which the qualitative data was generated. Thus, the information gained through the following quantitative data collection techniques is merely highlighted in the analysis portion of this thesis:

- o Work Sampling
- o Foreman Delay Survey
- o Project Documents
- o Time-Lapse Photography

Accordingly, the major emphasis of the data analysis for this thesis was qualitative in nature. A significant effort was made to evaluate the satisfactions and dissatisfactions of the HOTS construction personnel as identified through their responses to formal interview questionnaires and informal contacts with the researcher. Further, these qualitative data were examined to determine the HOTS project manager's best courses of action in order to retain on the payroll for the duration of the construction the experienced group of foremen, journeymen, and helpers that had been assembled by midsummer 1986.

3.2 Work Sampling

Summaries of the results from the crew sampling performed at the HOTS construction project are listed in Figures 14 and 15. Tables 6, 7, and 8 contain detailed breakdowns of the observations classified during each 21 minute crew sample. Total observations in excess of 384 were recorded for each of the HOTS construction crews, thereby attaining a confidence level of at least 95 percent for each crew's data.

Interestingly enough, each of the four construction crews were engaged in effective work for almost the same percentage of the recorded observations: from 37 to 40 percent of the time. The differences in how these crews spent their time at the project,

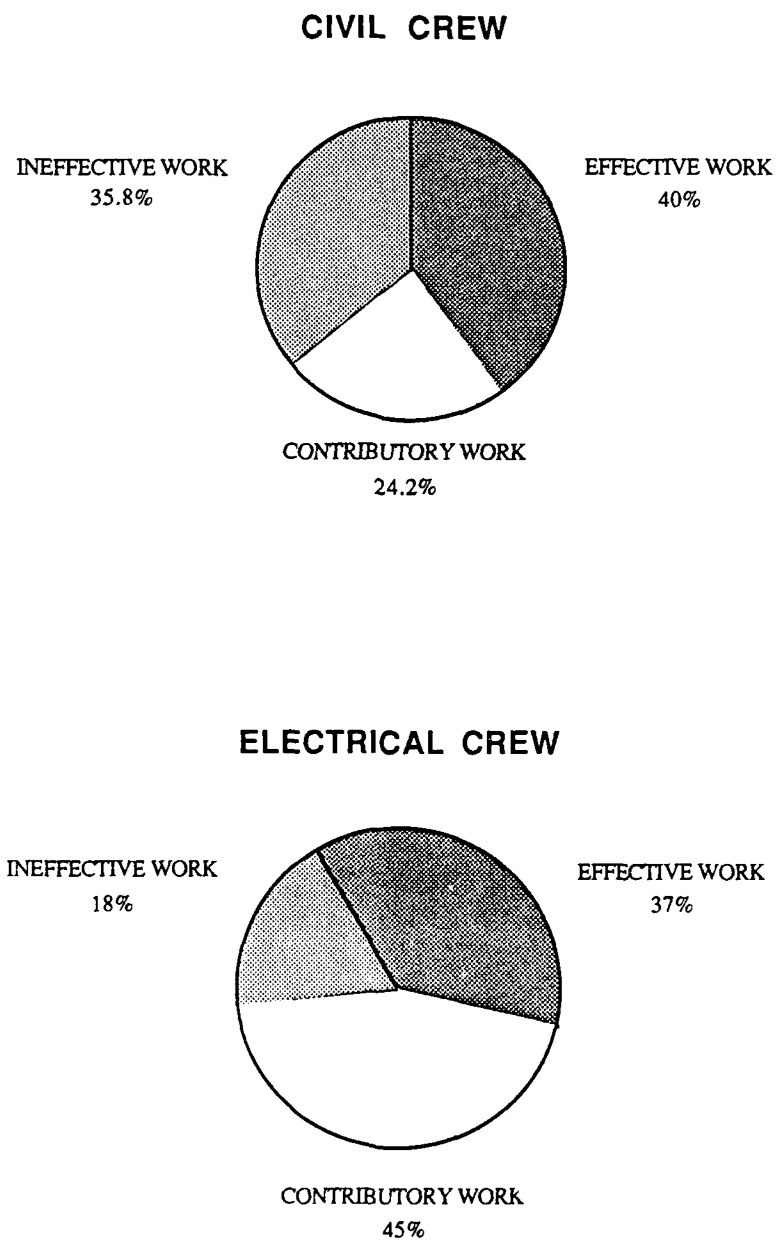


FIGURE 14

Summary of Crew Sampling Data: Civil and Electrical Crews

CIVIL CREW

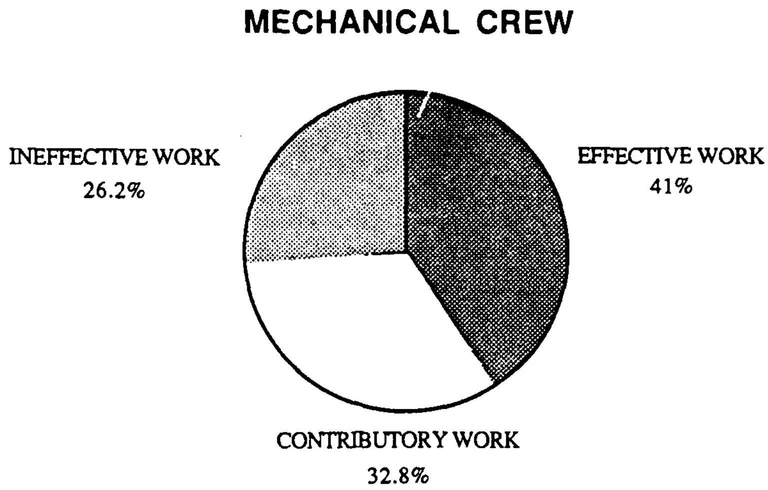
Sample Date	Effective	Contributory	Ineffective	Total
17 June 1986	15	13	26	54
17 June 1986	17	16	27	60
17 June 1986	25	18	20	63
17 June 1986	14	21	28	63
17 June 1986	25	21	17	63
18 July 1986	23	17	28	68
18 July 1986	44	14	26	84
18 July 1986	53	10	21	84
Total	216	130	193	539

ELECTRICAL CREW

Sample Date	Effective	Contributory	Ineffective	Total
20 July 1986	40	35	15	90
14 July 1986	29	43	12	84
14 July 1986	17	32	14	63
14 July 1986	20	40	24	84
14 July 1986	30	27	6	63
14 July 1986	30	23	10	63
Total	166	200	81	447

TABLE 6

Crew Sampling Data: Civil and Electrical Crews



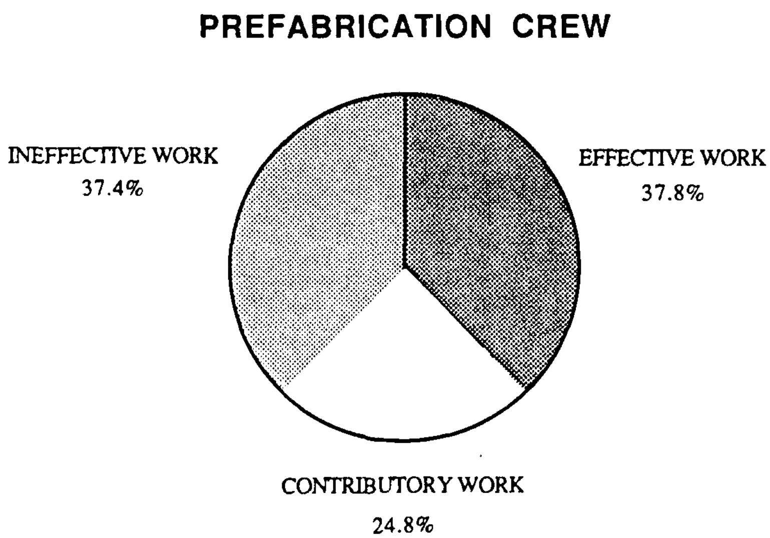


FIGURE 15

Summary of Crew Sampling Data: Mechanical and Prefabrication Crews

MECHANICAL CREW

Sample Date	Effective	Contributory	Ineffective	Total
18 June 1986	35	20	17	72
18 June 1986	41	19	30	90
18 June 1986	68	15	43	126
18 June 1986	52	30	44	126
18 June 1986	42	45	39	126
18 June 1986	59	35	32	126
13 Aug 1986	27	39	4	70
13 Aug 1986	39	49	17	105
13 Aug 1986	28	50	27	105
13 Aug 1986	17	25	6	48
TOTAL	408	327	259	994

TABLE 7

Crew Sampling Data: Mechanical Crew

PREFABRICATION CREW

Sample Date	Effective	Contributory	Ineffective	Total
16 June 1986	10	4	49	63
16 June 1986	22	24	17	63
16 June 1986	34	15	14	63
20 June 1986	44	20	20	84
15 July 1986	41	18	25	84
15 July 1986	25	30	29	84
15 July 1986	30	17	37	84
15 July 1986	28	21	35	84
16 July 1986	23	28	31	82
16 July 1986	28	24	32	84
17 July 1986	27	12	33	72
17 July 1986	27	23	36	86
17 July 1986	46	15	23	84
TOTAL	385	251	381	1017

TABLE 8

Crew Sampling Data: Prefabrication Crew

then, lay in the amounts of contributory work and ineffective work that were performed during the observation periods. The electrical crew exhibited the least amount of ineffective time; whereas, the prefabrication crew displayed the greatest amount of unproductive work.

The electrical crew's relatively high degree of activity might be explained by the fact that it was a small crew: 3 to 4 helpers and no journeyman. Moreover, for an extended period during the summer the average age of an electrical crew member was 21 years. The experience levels of these electrical helpers ranged from only a few weeks to a few years. Yet, these crew members more than any other crew members at the HOTS project, took pride in the fact that they formed a young, energetic group. Further, they advanced the attitude that whatever they lacked in experience, they made up for in hustle at the work site. The electrical helpers even boasted that they had "run off" two journeyman electricians from the job because these journeymen could not keep pace with the helpers. Consequently, the electrical foreman assumed the role of teacher or trainer for his relatively inexperienced, but enthusiastic crew members. In response to this situation, the electrical helpers consistently demonstrated throughout the summer that they were eager to learn on the job site. Accordingly, this group of construction workers was quite active when observed at HOTS sites, engaged mostly in effective and contributory tasks.

The prefabrication crew was also a small crew: two welders, one journeyman pipefitter, and one pipefitter helper. However, the activity level of this crew was dictated more by the material constraints of the HOTS project than the level of any other crew. In fact, the two welders knew exactly how many pipe welds had to be accomplished each workday in order to remain within the materially constrained project schedule. This amount of daily welding work eventually proved to be a maximum level, since each welder was experienced enough to achieve this level quite easily prior to the close of the workday. Hence, a significant portion of the welders' daily routine seemed to consist of activity intended simply to pass time. In this way, the welders were assured of accomplishing only the number of welds needed to attain the daily production norm that had been established by the prefabrication crew members. Ultimately, the norm was granted certain legitimacy when the crew foreman included this production figure as one of his planning tools. Indeed, the foreman's action was only natural considering the alternative to the use of a constrained daily production objective: the prefabrication crew could fit and weld pipe faster than the finished pieces were required on the HOTS sites and faster than the unfinished pieces were delivered by Shell California Production, Incorporated to Becon's project storage yard.

Ineffective work also comprised a significant portion -- 35.8 percent -- of the recorded observations for the civil crew.

This was the largest crew on the site, consisting of two journeyman carpenters and six helpers. With the exception of these two journeymen, the civil crew was also a young, inexperienced group. The average age of a civil helper was 19.5 years old; the experience levels of these helpers ranged from a few weeks to a maximum of six months. The civil foreman was a people-oriented leader who adapted well to his requisite role as a trainer/teacher. In any case, virtually the same worker makeup in the electrical crew yielded for that crew about one half the level of ineffective work demonstrated by the civil crew.

One possible explanation for this disparity between the crews would be that the activity level of the civil crew was constrained to a degree second only to the prefabrication crew's constraints. In contrast to the prefabrication crew, the civil crew's constraints resulted mainly from the incremental supply to Becon from SCPI of design information. In fact, at various times throughout the summer the civil foreman was encouraged by project management to slow his crew's progress in completing the civil portion of HOTS sites because of the constrained availability of design information for succeeding HOTS.

Also of note was the fact that the civil personnel, unlike any of the other construction crew members, routinely found themselves dispersed in groups of 2 or 3 workers at various sites throughout the Belridge Oil Field. The civil work at each HOTS was easily organized into subtasks which were accomplished

by small crews working simultaneously at several sites. Hence, the civil crew foreman became a roving supervisor. An observed result of assigning these civil subgroups throughout the 17 square mile project area was that the helpers exhibited a tendency to take breaks more frequently than normal whenever the foreman was absent from the immediate workplace. Also evident in observing these civil subcrews at work -- especially when no journeyman was present -- was the inactivity that occurred among the civil helpers who had finished their assigned tasks and were waiting for the foreman to arrive and issue further work instructions. Lastly, some inactivity was bound to result among civil crew members as they waited for transportation to succeeding work locations, after having terminated all tasks at the present work site. Although the civil crew maintained two trucks, the crew was often divided into more than two subcrews, thereby resulting in some delays because of a lack of sufficient transportation. Thus, any one of the aforementioned situations might explain why the civil crew's sampling data displayed a larger percentage of ineffective work than did that of the electrical or mechanical crews.

The activity level of the mechanical crew fell somewhere in the middle of the crew sampling extremes already noted. This crew consisted of a journeyman pipefitter, a welder, and a few pipefitter helpers. In addition, the mechanical crew's foreman was the only supervisor at the HOTS project who consistently worked

alongside his crew members. It should be mentioned that the mechanical crew had to perform the largest amount of scheduled, on-site man-hours of any of the construction crews to complete each HOTS. Traditionally, the mechanical crew's aboveground pipe tasks at each site contained little or no scheduled float time. In other words, the rate at which the mechanical crew completed its portion of work at a site played a major role in establishing the final completion date for that site.

3.3 Delays

A total of 72 foreman delay surveys were completed by HOTS project supervisors from 19 May to 13 June 1986: four surveys per each of the 18 workdays during that period. Of the 72 FDS's, 55 were submitted with the annotation "no delay" on the form. The remaining 17 forms listed numerous categories of delays. Of these categories, none was repeated more than three times. Likewise, no discernable trends in HOTS project delays were identified upon examining the entries on the 17 FDS's. A summary of the categories for the 17 listed delays is as follows:

- o Equipment Breakdowns - 2 each
- o Late Arrival of Schedule Readimix Concrete - 2 each
- o Field Site Changes - 2 each
- o Interference from an External Contractor - 2 each
- o Interference from Another Becon Construction Crew - 1 each
- o Insufficient Water to Complete Backfill - 3 each
- o Tools/Materials Left at Home - 2 each
- o Miscellaneous - 3 each

For the most part, these delays represented isolated incidents in the daily HOTS project activities. Because the site manager

reviewed each FDS, he gained a greater appreciation for some of the minor delays occassionally experienced by the construction crews. In addition, the project manager took action, when appropriate, to eliminate the causes of these minor delays. For example, Becon's project management staff routinely coordinated with the other general contractors at the Belridge Oil Field in order to prevent interference delays. Similarly, Becon's procurement manager developed a good working rapport with the local readimix concrete supplier so as to insure the timely delivery of concrete to the project site. Lastly, a make-shift water tank was installed on one of the civil crew's trucks in order to provide a mobile, ready source of water in sufficient quantity to support backfill operations.

On 16 June 1986, the site manager and the researcher agreed that no new, major project constraints were revealed in the results of the FDS's completed during the previous four workweeks. For this reason, the subsequent use of FDS's at the HOTS project was discontinued.

3.4 Productivity

As mentioned previously in Section 2.2, the HOTS project manager used as his measure of productivity the total direct man-hours expended by construction crews in the completion of individual HOTS sites. These totals for each test station were extracted from the project's Labor Analysis Report. Additionally, the performance of the prefabrication crew was evaluated using the computed average

man-hours to complete one cubic inch of pipe weld. This computation was performed by collecting from the crew foreman the quantity and type of pipe welds performed each week in the prefabrication operation. After the field engineer reviewed and verified this weekly production information, conversion factors were utilized to convert the production figures into cubic inches of pipe weld. The prefabrication crew's direct work man-hours per week were then extracted from the LAR and the productivity measure -- man-hours per cubic inch of weld -- computed. The productivity of the yard crew's efforts, comprising mainly indirect project man-hours, was tracked on a percent of budget basis. No attempt was made in this study to evaluate the yard crew's productivity any further.

Figures 16, 17, and 18 depict the individual totals and the cumulative averages of man-hours expended per HOTS by the civil, electrical, and mechanical crews, respectively. Tables 9, 10, and 11 list the corresponding data, as extracted from the weekly LAR's, used to prepare these figures. Note that a total of 29 HOTS were completed in their entirety through the final week of August 1986.

Figure 19 and Table 12 apply to the prefabrication crew's productivity data. Although the construction period studied encompassed 34 workweeks, only 22 construction weeks were displayd on this figure and table. Aside from the project's first three workweeks in January 1986, during which mainly project mobilization was accomplished, the last two months of the study period were excluded from the prefabrication crew's productivity analysis. The

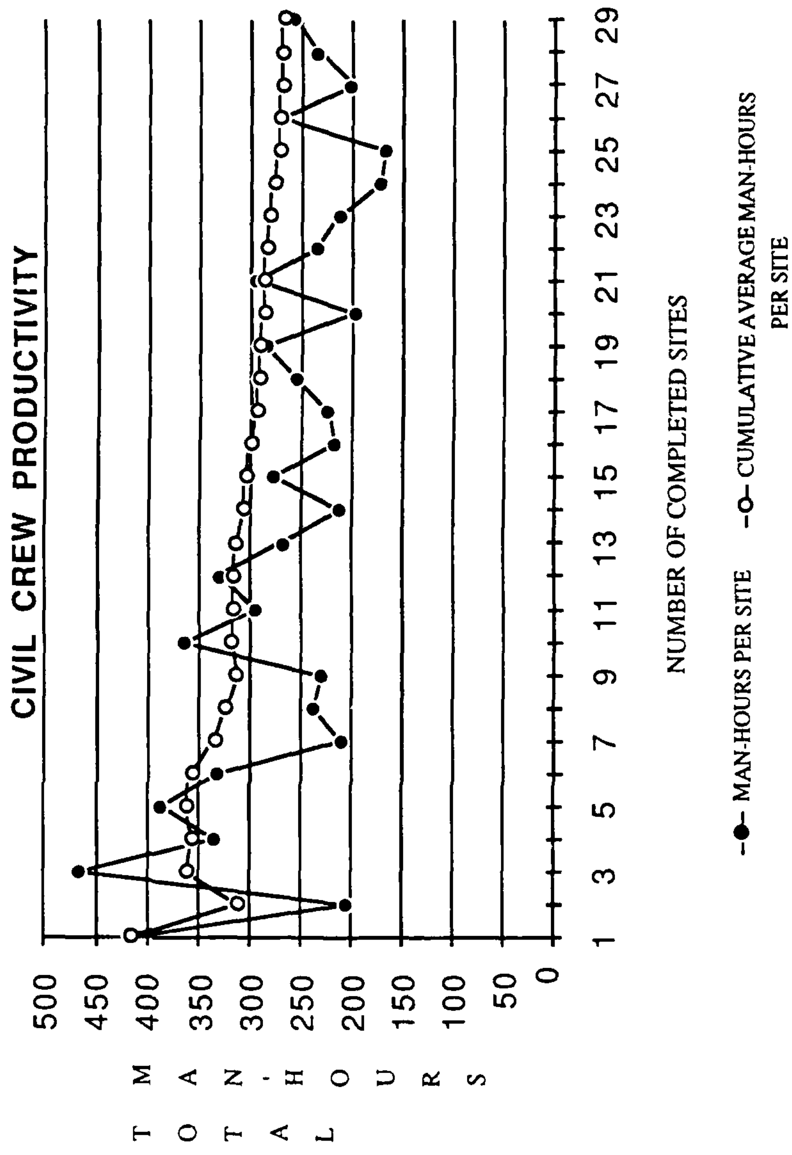


FIGURE 16

Productivity of the Workforce: Civil Crew

CIVIL CREW

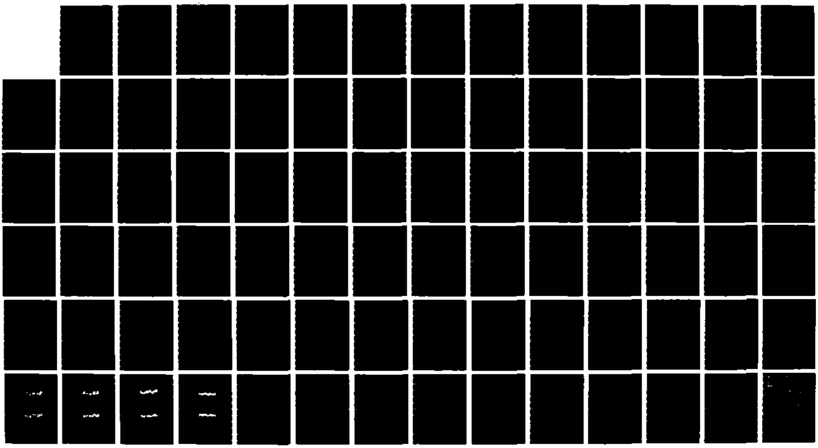
Site	Compl Date	Composition 5-Well Manifold	Composition 10-Well Manifold	MH/Site	Cumulative Ave MH/Site
193	12 March 1986	1	3	417	417
162A	14 March 1986	0	4	204	311
162B	14 March 1986	1	4	466	362
191	25 March 1986	1	4	335	356
116	25 March 1986	1	4	386	362
192	27 March 1986	0	5	331	357
187	2 April 1986	0	4	209	335
185	2 April 1986	1	4	237	323
105	8 April 1986	0	4	229	313
124	17 April 1986	1	4	365	318
173	21 April 1986	1	4	295	316
123	28 April 1986	1	4	329	317
121A	30 April 1986	1	4	267	313
121B	7 May 1986	0	4	212	306
122	15 May 1986	0	5	277	304
154	21 May 1986	1	4	217	299
152	29 May 1986	1	4	224	294
168	5 June 1986	0	4	254	292
156	11 June 1986	0	5	285	291
159	18 June 1986	0	5	198	287
158	25 June 1986	0	5	294	287
198	3 July 1986	1	4	234	285
155	11 July 1986	1	4	212	282
102	22 July 1986	1	4	172	277
163	30 July 1986	1	4	166	273
107	6 August 1986	0	5	269	272
103	13 August 1986	1	4	201	270
104	20 August 1986	1	4	235	269
186	27 August 1986	1	4	257	268

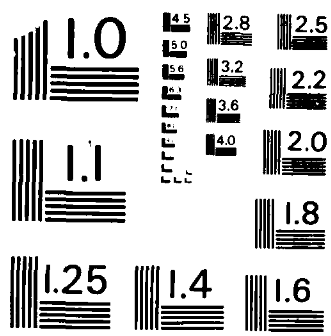
TABLE 9

Productivity of the Work Force: Civil Crew

AD-A175 231 HUMAN FACTORS IN THE MANAGEMENT OF BECON CONSTRUCTION 2/2
COMPANY'S HEAVY OIL TEST STATION PROJECT(U) ARMY
MILITARY PERSONNEL CENTER ALEXANDRIA VA D MAURER

UNCLASSIFIED NOV 86 F/G 5/1 NL





MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

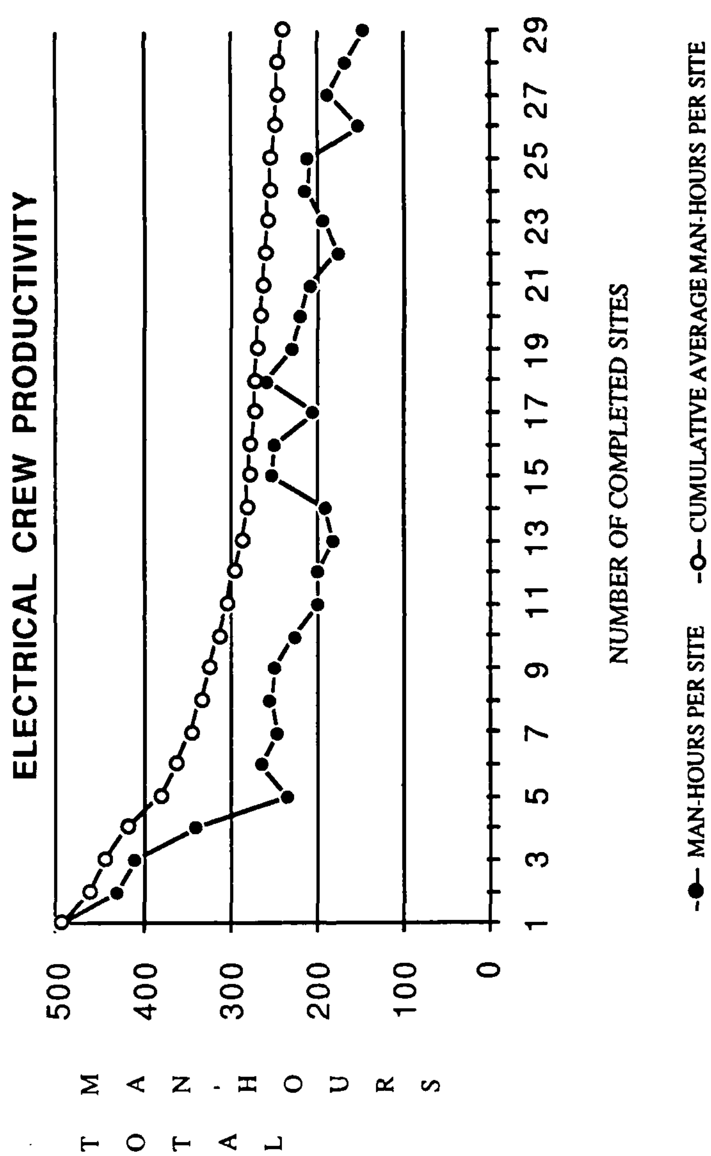


FIGURE 17

Productivity of the Work Force: Electrical Crew

ELECTRICAL CREW

Site	Compl Date	Composition: 5-Well Manifold	Composition: 10-Well Manifold	MH/Site	Cumulative Ave MH/Site
193	12 March 1986	1	3	494	494
162A	14 March 1986	0	4	432	463
162B	14 March 1986	1	4	410	445
191	25 March 1986	1	4	341	419
116	25 March 1986	1	4	235	382
192	27 March 1986	0	5	265	363
187	2 April 1986	0	4	247	346
185	2 April 1986	1	4	254	335
105	8 April 1986	0	4	249	325
124	17 April 1986	1	4	227	315
173	21 April 1986	1	4	200	305
123	28 April 1986	1	4	200	296
121A	30 April 1986	1	4	181	287
121B	7 May 1986	0	4	192	281
122	15 May 1986	0	5	253	279
154	21 May 1986	1	4	249	277
152	29 May 1986	1	4	204	273
168	5 June 1986	0	4	258	272
156	11 June 1986	0	5	228	269
159	18 June 1986	0	5	219	267
158	25 June 1986	0	5	208	264
198	3 July 1986	1	4	177	260
155	11 July 1986	1	4	193	257
102	22 July 1986	1	4	213	255
163	30 July 1986	1	4	210	254
107	6 August 1986	0	5	152	250
103	13 August 1986	1	4	187	247
104	20 August 1986	1	4	168	245
186	27 August 1986	1	4	146	241

TABLE 10

Productivity of the Work Force: Electrical Crew

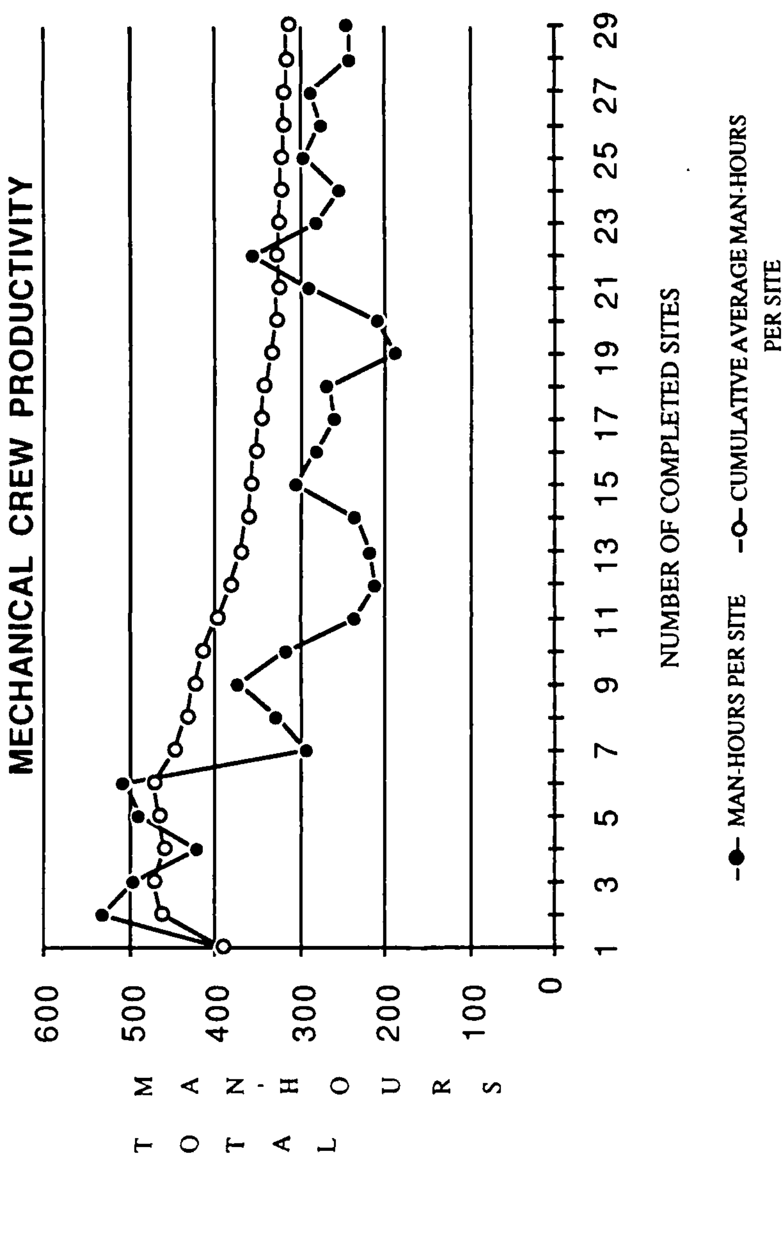


FIGURE 18

Productivity of the Work Force: Mechanical Crew

MECHANICAL CREW

Site	Compl Date	Composition: 5-Well Manifold	Composition: 10-Well Manifold	MH/Site	Cumulative Ave MH/Site
193	12 March 1986	1	3	392	392
162A	14 March 1986	0	4	533	463
162B	14 March 1986	1	4	497	474
191	25 March 1986	1	4	422	461
116	25 March 1986	1	4	489	467
192	27 March 1986	0	5	509	474
187	2 April 1986	0	4	294	448
185	2 April 1986	1	4	328	443
105	8 April 1986	0	4	374	426
124	17 April 1986	1	4	318	416
173	21 April 1986	1	4	236	399
123	28 April 1986	1	4	212	384
121A	30 April 1986	1	4	220	371
121B	7 May 1986	0	4	237	362
122	15 May 1986	0	5	306	358
154	21 May 1986	1	4	282	353
152	29 May 1986	1	4	260	348
168	5 June 1986	0	4	268	343
156	11 June 1986	0	5	190	335
159	18 June 1986	0	5	211	329
158	25 June 1986	0	5	290	327
198	3 July 1986	1	4	357	328
155	11 July 1986	1	4	282	326
102	22 July 1986	1	4	255	323
163	30 July 1986	1	4	296	322
107	6 August 1986	0	5	276	321
103	13 August 1986	1	4	288	319
104	20 August 1986	1	4	243	317
186	27 August 1986	1	4	245	314

TABLE 11

Productivity of the Work Force: Mechanical Crew

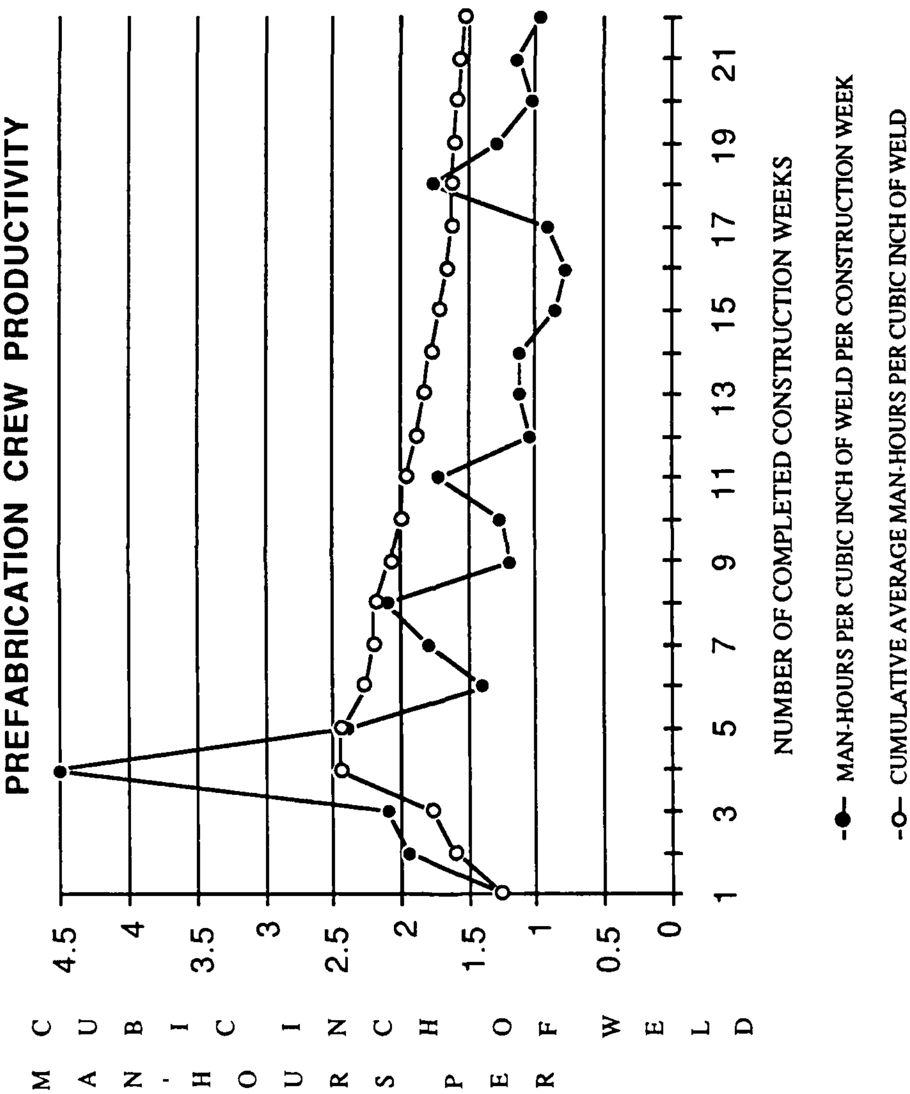


TABLE 19

Productivity of the Work Force: Prefabrication Crew

PREFABRICATION CREW

Construction Week Ending	MH/in^3 Weld	Cumulative Ave MH/in^3 Weld
1 February 1986	1.26	1.26
8 February 1986	1.95	1.61
15 February 1986	2.1	1.77
22 February 1986	4.5	2.45
1 March 1986	2.4	2.44
8 March 1986	1.4	2.27
15 March 1986	1.8	2.20
22 March 1986	2.1	2.19
29 March 1986	1.2	2.08
6 April 1986	1.26	2.00
13 April 1986	1.71	1.97
20 April 1986	1.04	1.89
27 April 1986	1.12	1.83
3 May 1986	1.12	1.78
10 May 1986	.86	1.72
17 May 1986	.78	1.66
24 May 1986	.92	1.62
31 May 1986	1.76	1.63
7 June 1986	1.29	1.61
14 June 1986	1.03	1.58
21 June 1986	1.14	1.56
28 June 1986	.97	1.53

TABLE 12

Productivity of the Work Force: Prefabrication Crew

reason for this exclusion lay in the fact that the prefabrication crew was heavily engaged in construction operations external to the HOTS project during July and August 1986. For instance, from 30 June to 10 July 1986 the prefabrication operation was essentially shut down as the crew members were loaned to the second Becon construction project at the Belridge Oil Field. Their services were required to construct 1800 feet of steam line, a task for which the second project had too few workers. Then on 18 July 1986, one of the welders in the prefabrication crew was fired because of disciplinary reasons. Consequently, the nature of the prefabrication operation was in a constant state of change in July 1986.

Starting on 7 August 1986 and lasting through to late August 1986, the prefabrication crew was heavily committed to construction operations at the vapor recovery system project, the small job awarded to Becon's HOTS project management by SCPI in late July 1986. On 14 August 1986, the one remaining welder on the prefabrication crew was terminated because of poor quality welds; his welds had failed X-ray testing the previous three workweeks. Hence, a search then began to procure two new, certified welders for the prefabrication crew. As a result of these changing events in the life of the prefabrication crew from July to August 1986, the crew's production data for this same period were of little use to the HOTS project manager for comparative analysis. Therefore,

these data were not included in the productivity information presented in this thesis.

As noted in Tables 9, 10, and 11, the test stations were not identical in terms of composition. However, they were treated as such by Becon management for the purpose of budgeting construction operations at the project site. For this reason, the site manager quite naturally utilized in his comparisons of construction crew productivity the direct work man-hours from every HOTS. So too were these data compared in their presentation for this thesis.

Another factor not indicated in the data comparison for the construction crews was the distance from the project headquarters to individual work sites. Whether or not this factor impacted on the productivity of each crew was not known since this site location information was never accumulated. In spite of this absence of site distance factors in the comparison of the construction crews' productivity, one significant observation related to HOTS locations is now included. Aside from the transportation time to and from sites -- a factor experienced equally by the civil, electrical, and mechanical crews -- it was asserted that the productivity of the mechanical crew was impacted most negatively by the distance of each HOTS from the project storage yard. The reasoning behind this assertion was the fact that the mechanical crew was the only crew at the project which, of necessity, maintained tools in gang boxes. (The nature of the civil and electrical crew tools enabled them to

be secured in the project storage yard overnight and transported daily to the work site.)

These gang boxes were cumbersome, requiring either the crane or the boom truck to load and unload the boxes at HOTS work locations. Thus, the act of moving gang boxes was an added support task for the mechanical crew whenever this crew started work at succeeding test stations. Moreover, the gang boxes had to be returned to the project storage yard at the close of business every Friday for security over the weekend. This weekend storage of gang boxes also necessitated their movement to the workplace first thing on Monday mornings. These movements of gang boxes also mandated careful coordination by the mechanical crew foreman for the support of lifting equipment at the project. If this equipment was nonoperational or unavailable when needed by the mechanical crew, the crew members experienced still further delays at the job site because of the lack of one of the essential elements of work: tools.

In any case, a review of the data in Figures 16 through 19 revealed that each construction crew experienced continual improvements in their cumulative average man-hours per unit of output as work progressed during the study period. The electrical crew experienced the largest percentage of improvement over the 8 months, from a cumulative average of 494 man-hours per site to 239 man-hours per site: a reduction of 51.6%.

One possible reason for the electrical crew exhibiting the largest improvement would be that the electrical tasks were more technical or complicated in nature than the tasks of the other crews. Consequently, these tasks afforded the young, relatively inexperienced electrical crew members a greater opportunity to achieve gains in their productivity. Percentage reductions in man-hours per unit of output recorded for the prefabrication, civil, and mechanical crews were 37.5%, 35.7%, and 19.9%, respectively. No evaluation was made in this study of the budget information used to track the productivity of the members of the yard crew.

3.5 Review of Time-Lapse Photography

After viewing several time-lapse films on 15 July 1986, the site manager granted his approval for the researcher to schedule with the project superintendent to show the filmed project activities to the appropriate construction crews. TL films were shown to three crews on 17 and 18 July 1986: prefabrication, civil, and mechanical. In addition, the project field engineer and the superintendent viewed these films at a separate showing that day. The electrical and yard crews participated in TL film showings on 14 August 1986. Each of the project crews was accompanied by the crew foreman during these sessions. Furthermore, the project

manager, superintendent, and field engineer viewed films along with some of these crews, as schedules permitted.

The showing of the TL films to project personnel served two functions. First of all, it satisfied the curiosity of numerous HOTS workers regarding the nature and purpose of this unique form of photography on the job site. More importantly, the TL film sessions served as a form of team building for the crew members.

The potential value of these team building exercises was not taken lightly. At the start of each session, the concept of TL photography was explained to the crew. Thereupon, the researcher, who served as group facilitator, stated the reason for the crews to view the films: to generate discussion among crew members concerning how to accomplish the photographed tasks more quickly or efficiently. It was also emphasized that no one would be terminated from the project as a result of actions recorded on film.

As the films were shown, the researcher pointed out incidents of particular interest such as events and obstacles causing delays to worker output. Discussion of these and other photographed occurrences was solicited and encouraged from crew members while the movie projector was still operating. The projector was easily stopped, reversed, or slowed, as needed, during these discussions. Recognizing the importance of allowing crew members the opportunity to initiate the majority of the comments, each crew foreman chose not to dominate the conversation as the films were

shown. Following the films, crew members were asked to summarize out loud what they had observed and learned from witnessing the TL recordings of their activities.

For the most part, the crew members were attentive and receptive during the film showings. They offered constructive evaluations of the activities that they had viewed. Plus, they made suggestions regarding how to accomplish these activities more efficiently and effectively. For example, the prefabrication and mechanical crews identified several obstacles in the work area that needed to be moved. Civil crew members noticed an excessive amount of worker movement to and from the tool box when tool belts were not worn by the journeymen and helpers. Additionally, they discussed ways to speed the process of setting the elevations for items to be embedded in concrete. Lastly, the electrical crew brainstormed various new locations for tools and materials at a HOTS so as to enhance the efficiency of the aboveground electrical tasks.

In August 1986, the researcher approached two of the three foremen whose crews had witnessed TL films in July 1986. (The third foreman was on vacation at the time.) They reported no noticeable short term benefit to crew operations as a result of their crews' participation in the TL film sessions. Both foremen admitted having identified in July several work methods improvements that they wanted to implement within their crews. However, as of 14 August 1986, neither foreman had had an opportunity to initiate these improvements.

Still, it was hoped that the TL film viewings would benefit construction operations at the HOTS project in the long term for two reasons. The team building efforts represented by the film discussions should impact positively on the project crews in the future as they are presented with unique challenges to be resolved at the work place. Indeed, the opportunity afforded the crew members to devise work methods improvements while viewing TL film may have been especially valuable, considering the fact that a majority of the workers indicated in their questionnaire responses that the project foremen were highly receptive to worker input.

Secondly, the fact that Becon's project management made special arrangements to include all crew members in the effort to improve HOTS project operations should demonstrate management's care and concern for all individuals at the HOTS job site. It must be noted that the TL films were shown to workers in the air--conditioned project office and during the workday. In other words, the participants were paid by Becon to witness and discuss the TL films.

3.6 Absenteeism

Personnel manning and absentee data collected from the HOTS project's Daily Force Reports during the study period are depicted graphically and in tabular form in Appendix II. The project's manning strength reached a high of 57 construction workers in mid-March 1986. By the end of August 1986, this strength had

dropped to 30 personnel. For the 34 construction weeks included in the project study, the average absentee rate for each day of the workweek was as follows:

Workday	Percent of Work Force Absent
Monday	6.45%
Tuesday	3.73%
Wednesday	3.95%
Thursday	3.13%
Friday	5.55%

Thus, the HOTS project experienced a significantly higher percentage of worker absenteeism on Mondays and Fridays than on Tuesdays, Wednesdays, or Thursdays.

Of particular interest to the HOTS project manager was the fact that as the size of his construction crews shrank in the summer to levels lower than in the spring, there was a greater impact of individual crew member absences on daily construction operations. As previously discussed in Section 1.4, the project work force had become small enough in the summer so that the absence of key personnel created a critical skill shortage within one or more construction crews. Consequently, this situation merely reinforced the site manager's contention regarding certain critical skills that it was in the best interests of project management to sacrifice efficiency in personnel manning for the enhancement of flexibility in planning and scheduling of personnel resources at the work place.

3.7 Accidents

One lost-time accident occurred at the HOTS project during the 8-month study period. The injury was suffered by a welder in the mechanical crew at HOTS #122 on 23 April 1986 at approximately 10:50 am. The project's cherry picker crane was on the site to lift and position manifold skids. As the welder guided a 10-well manifold skid supported by the crane into a final resting position, the skid shifted, thereby pinching the tips of two of the welder's fingers between the structure of the hanging skid and that of a skid already positioned on its foundation. Although extremely painful, the welder's injury was not debilitating. He resumed light duty at the HOTS project on 29 April 1986, assigned temporarily to the prefabrication operation until his fingers had healed completely. Thereupon, he returned to the mechanical crew where he, in fact, preferred to work.

When the researcher spoke to the mechanical foreman and to the crane operator in May 1986 about the welder's accident, an interesting issue surfaced that pointed out the value of informal feedback collected at the project during the study. The foreman and the operator expressed concerns to the researcher that the crane's rated capacity was being exceeded whenever manifold skids were lifted. However, there was no way to confirm or refute their contention, since the loading chart for the project's crane was missing. Subsequently, the researcher queried the project superintendent and manager about the lack of a loading chart for the

crane. Not knowing that the chart was missing, they took immediate action to procure one. The loading chart arrived at the HOTS site a few days later and was examined to determine if the skid lift exceeded the crane's rated capacity. It did not, and lifting operations continued with the project's crane. However, the site manager expressed displeasure that the need for the loading chart had not been identified earlier by project personnel.

The field engineer at the project contended that the accident at HOTS #122 caused a noticeable decrease in the productivity of the mechanical crew at that site. (It is site 15 on the productivity figures displayed in Section 3.4.) The mechanical foreman supported this contention by noting that his crew accomplished little else the rest of the day that the accident occurred. However, this foreman also commented that HOTS #122 was the scene of tool theft from his crew's gang boxes a few days following the welder's accident. Subsequent to this theft, the crew experienced still further delays at that site by performing a tool inventory to determine which items had been stolen. (The missing tools -- including both corporate and privately owned items -- were eventually replaced by Becon.)

In addition, the mechanical crew expended at subsequent test stations man-hour totals that were similar in quantity to that expended at HOTS #122. Total mechanical man-hours for HOTS #198, completed on 3 July 1986, even exceeded the total for HOTS #122. Consequently, the impact of the 23 April accident on the

mechanical crew's productivity at HOTS #122 cannot be as readily isolated as advocated by the project's field engineer.

Five minor accidents occurred on the project site during the study period. None of these incidents resulted in lost-time for those involved. The accidents are summarized below:

- o 4 February 1986 - Injured ankle
- o 27 February 1986 - Pinched finger
- o 20 March 1986 - Chipped tooth
- o August 1986 - Mild heat exhaustion
- o August 1986 - Mild electrical shock

A few comments should be made about the HOTS project safety program. The project safety manager was a well-trained, experienced professional. A licensed emergency medical technician, the safety manager was a qualified first aid instructor and performed all project pre-employment physicals. Moreover, he had implemented at the HOTS project a proactive, inventive safety program that included Monday morning tool box safety meetings and two safety incentive award programs: one for foremen and another for project personnel as a whole. Finally, the safety manager doubled as the project procurement officer, a task that he pursued as vigorously as his safety responsibilities.

3.8 Weather

Weather data gathered from the National Weather Service Office located at the Kern County Airport, Bakersfield, California are summarized in Appendix III. Information regarding the relative humidity near the HOTS project location was not included in the

weather service's monthly publication of local climatological data. However, the researcher's personal experience from visiting the project site during the summer indicated that uncomfortably high relative humidities did not accompany the high daily temperatures of the summer months. In fact, the hottest daily temperatures in July and August 1986 occurred in conjunction with relative humidities that ranged from 20 to 40 percent. Thus, working outdoors in such conditions was not an unbearable experience.

In other words, the climate in Kern County, California is extremely dry, almost desert-like. Further, very little rainfall occurred at the project site during the 8-month study period; the work site experienced only one rain day -- in the spring -- from January to August 1986. Consequently, extremely dusty conditions prevailed at the Belridge Oil Field. In response, the project manager eventually arranged for the civil, electrical, and mechanical foreman to receive appropriate hardware to enable their crews to tap into existing water sources throughout the oil field for use in watering work sites to control dust. For some reason, these foremen rarely took advantage of this resource to help control the dust which, during windy periods, became quite an irritant to construction workers.

It was felt initially that the construction crews would experience a worsening of productivity during the intense summer heat of Kern County. Granted, the rate of improvement in each crew's cumulative average man-hours per unit of output was noticeably

less during the summer months than during the spring. Yet, improvements in each crew's productivity during the summer continued regardless of the heat. This leveling off in construction crew productivity might also be explained as the stable cost period of the learning curve phenomenon -- noted in Section 1.1 -- rather than as the result of reduced worker efficiency during the summer heat. Unfortunately, the study did not last long enough to gather productivity data from the fall season -- a period of daily high temperatures that are obviously lower than those of the summer -- for use in a comparative analysis.

Finally, the climate of the project site proved not to be a significant factor in the satisfactions and dissatisfactions of the HOTS project personnel, as determined from the responses to the questionnaires. This topic will be covered in greater detail in section 3.10.

3.9 Worker Satisfactions

Seven journeymen and twenty-three helpers responded to questionnaires during the course of the study. Their answers to the question, "What gives you the most job satisfaction?" reflected many of the same sentiments expressed by those interviewed in Dr. John D. Borcherding's pilot study.[45] For example, the most frequent response offered by HOTS project craftsmen indicated that they gained satisfaction by performing the work itself. In other words, completing the tasks at the workplace proved satisfying to the HOTS

project personnel as evidenced by replies such as, "It's hard work and I'm proud of it;" "When I'm tired, I know I had a hard day at work;" "Knowing what I do comes out right;" "Running conduit;" and "Having the work come out looking nice." Twenty out of thirty interviewees responded in this manner.

The second most common satisfier among HOTS craftsmen was their feeling of accomplishment having completed a tangible physical structure. "Seeing a completed HOTS" and "The finished product" were typical answers offered by eight workmen. Here again, this satisfier was also prominent among the pilot study's data.[46]

On the other hand, the third most common satisfier among HOTS construction personnel was an issue not brought out in the pilot study's results: the opportunity for the HOTS workers to learn trade skills on the job site. Five helpers stated this satisfaction in direct response to the job satisfaction question during the interview. In addition, eight other helpers replied in like manner to the interview questions, "Other than money, why is your job important to you?" and "What do you like about your trade now?" Thus, it appeared that the makeup of the HOTS work force was such that the numerous helpers received satisfaction from their on-the-job training in construction skills. Indeed, among the twenty-three helpers interviewed, the average amount of construction experience prior to their joining the HOTS project was slightly less than two years. (Average experience levels among crews varied

from a low of 5 weeks per civil crew member to a high of 3.3 years per yard crew member.)

Also unlike the pilot study's identified satisfactions,[47] HOTS construction workers did not specifically list social relationships at the work place as satisfying. However, good social relations among crew members was the overwhelming reason offered by these workers in response to the question, "What makes a crew perform well together?" Twenty-three respondents noted good interpersonal relations among crew members as the mark of a good crew. Moreover, all thirty interviewees replied that gaining the respect of their fellow workers was important to them. Consequently, it was safe to say that the HOTS crew members placed great value on good social relations at the work place.

Clearly the majority of journeymen and helpers at the HOTS project enjoyed their work; twenty-five responded accordingly. Furthermore, few workers volunteered suggestions to the question, "Is there anything management could do that would make your job more satisfying?" Seven workers suggested a raise in wages; however, the remainder of the journeymen and helpers stated either "No;" "I can't think of anything;" or "Nothing more than they're doing right now." Twenty-nine respondents felt that company social functions provided additional job satisfaction. Most cited the two Becon project picnics held during the summer when answering this question. A crew bonus received twenty-one votes as a reward for high

performance. Five workers had no preference between a recognition dinner or a bonus; while, only four preferred the dinner.

In summary, the journeymen and helpers at the HOTS project expressed most frequently the following job satisfactions:

- o The work itself/Completed task
- o Tangible physical structure
- o Opportunity to learn trade skills

Because so few foremen comprised the first-line supervision of the HOTS project work force, all of the foremen responses to the question regarding job satisfactions are listed below, but in no specific order:

- o Tangible physical structure
- o Completing a job
- o Keeping busy; Being under constant pressure
- o Seeing the helpers learn and improve their skills
- o Completing a neat, well done job; Being ahead of schedule

Although some of these responses were similar, they varied enough to be listed separately. At least one foreman specifically acknowledged as satisfying his role as a trainer for the relatively inexperienced helpers that predominated among the HOTS project work force. Four of the five foremen felt that they were paid enough by Becon for their efforts. In addition, four foremen thoroughly enjoyed their work at the HOTS project; responses ranged from "I enjoy it very much" to "I love it!" The fifth foreman indicated that he considered his work boring.

Finally, no comparison was made between the HOTS foreman satisfiers and those noted by foremen interviewed during the pilot

study. The tiny sample size of foremen at the HOTS project in relation to that of the pilot study made such a comparison unwarranted.

3.10 Worker Dissatisfactions

As also evidenced in Dr. John D. Borcherding's pilot study, the dissatisfactions offered by the HOTS construction crew members during the interviews did not constitute mere opposites of the previously mentioned project satisfiers.[48] Strangely enough, the reply most prevalent among the interviewees in answering the question, "What gives you the most job dissatisfaction?" was the null response: "I can't think of anything." Nine of thirty construction workers so replied. Was the HOTS project environment so void of dissatisfiers that these nine respondents were unable to think of anything when answering the question? Or, were these nine crew members uneasy about responding in a negative fashion about their work. The location of the job satisfaction question early on in the interview might have played a role in discouraging responses initially, until the interviewer and interviewee had broken the ice, so to speak. Indeed, worker responses to subsequent interview questions about how foremen and management could upset crew members and concerning why a crew performs poorly revealed several potential sources of dissatisfaction. Regardless, no single answer to the interview question dealing directly with job dissatisfactions was repeated by more than four interviewees.

Wasting time or waiting on the job site was listed as a dissatisfier by four crew members. Two of these respondents were assigned to the prefabrication crew and the two others were yard crew members. Specific responses included, "The lack of things to do" and "Being bored; having nothing to do." Five personnel felt that having on the crew unproductive workers or workers with poor attitudes was dissatisfying. Poor workmanship by the crew was mentioned as a dissatisfaction by three crew members. The remainder of the responses to the job dissatisfaction question varied widely. Only two individuals expressed dissatisfactions with the weather at the job site. Two others cited the work itself as dissatisfying. Finally, two HOTS crew members stated as a source of dissatisfaction their inability to complete a task once it had begun. In summation, the dissatisfactions that predominated among the HOTS work force responses -- other than the null response -- were the following:

- o Wasting time/Lack of work
- o Unproductive workers/Workers with poor attitudes
- o Poor workmanship by the crew

In comparing these responses to those revealed in the pilot study's data, it appeared that "wasting time" as a source of dissatisfaction was unique to the HOTS project work force.[49] Absent from the answers given by those interviewed at the HOTS project were "poor interpersonal relations" and "unfair job assignments," the first and fourth most prevalent sources of job dissatisfaction for the pilot study's interviewees.[50] However, these additional

sources of worker discontent were revealed by HOTS project workers as potential dissatisfactions, as previously noted, in their responses to questions regarding crew performance and supervision.

Once again, the dissatisfactions offered by the five foremen at the HOTS project are listed below in no particular order:

- o Lack of management's confidence in and respect for my abilities
- o Project personnel who don't answer the radio when being paged
- o Sloppy work (cited by two foremen)
- o Failure to meet schedules

In like manner to the reasoning stated in Section 3.9, no comparison was warranted between the dissatisfiers of the HOTS project foremen and those of the foreman who participated in the pilot study.

3.11 Worker Retention

The analysis of issues relating to retaining the work force at the HOTS project included three areas: a review of the project's turnover rate during the 8-month study period, the preferred characteristics of the HOTS work environment as revealed in questionnaire responses, and an insight to some of the attitudes of crew members and foremen, also identified from questionnaire data.

From January to the end of August 1986, ninety-three foremen, journeymen, and helpers were hired at the HOTS project; sixty-three employee terminations occurred during this same period. These personnel actions equated to a project turnover rate of slightly

less that 68%. In mid-May, when the site manager first expressed his concern to the researcher regarding the retention of the HOTS work force, the personnel turnover rate exceeded 58%. Consequently, it appeared that the site manager's concern was warranted. A monthly summary of personnel hires and terminations at the HOTS project follows:

Month	Hires	Terminations
January 1986	31	2
February 1986	29	8
March 1986	18	20
April 1986	0	11
May 1986	2	7
June 1986	4	3
July 1986	2	7
August 1986	7	5
Total:	93	63

Of these sixty-three terminations, the majority of the departing workers voluntarily quit the HOTS project. The exact reasons for these employees voluntarily leaving the project were never recorded, since no formal exit interviews of these departees were conducted by project management. A review of the major categories of employee terminations is listed below:

Voluntary Quit -	36
Transfer to Another Becon Project -	17
Unqualified -	3
Disciplinary Reasons -	7
Total:	63

Fortunately for the site manager, none of these terminated employees were project foremen. Therefore, continuity of construction tech-

niques was generally preserved at the HOTS project despite the high incidence of personnel turnover during the study period.

In responding to the final question of each interview, "Do you plan to stay on for the duration of this job (projected completion in November 1987)?" all of the foremen answered in the affirmative; while, only two construction workers indicated that they intended to terminate the project prior to its overall completion. (Twenty-one workers answered "Yes"; four stated "Probably"; and three crew members were unsure about their plans to stay on the HOTS project.) Yet, twelve helpers departed the HOTS project after June 1986, when the majority of the interview questionnaires had been completed. Of these twelve departees, one was anticipated; he was a college student hired temporarily during the summer. Additionally, five other helpers were terminated for disciplinary or quality control reasons. Hence, that left six construction workers who left the project after having indicated during their interviews in June that they intended to remain at the job site until November 1987.

Had something about the job site conditions caused these six helpers to quit prior to the end of the project? In fact, what were the characteristics of the work environment at the HOTS project which the craftsmen valued? In citing examples to answer the question, "How should a good foreman manage a crew?" ten of thirty respondents stated that an effective foreman was one who told his crew members what to do, then allowed them to do it. Also

offered by the construction workers as traits of a good foreman were strong leadership, good communication skills, equitable treatment of subordinates, easy to get along with, knowledgeable, and good planning ability. No null responses were recorded.

Five null responses were logged, however, in reply to the question, "what could your foreman do to really upset or frustrate you?" Answers in the general category of poor supervisory relations predominated: fourteen of thirty respondents. Responses in this category included, "Be unfair;" Nag me;" "Constantly yell at me even though I'm trying my best;" and "Continually ride may back." The failure of a foreman to recognize a craftsman's efforts was expressed by five interviewees as a source of frustration: "If he told me I'm not doing my job, when I know I am" and "If I ran pipe and thought it looked good, but my foreman told me it was no good and to rip it out."

Little contact with the HOTS project management was stated by fourteen workers as an excuse for having no reply to the follow-on question, "What could management do to really upset you or frustrate you?" Most notable among responses offered to this question were a cut in pay (five respondents) and inequitable treatment of individual construction personnel (five respondents).

Good personal relations (fourteen respondents), teamwork (eight respondents), and cooperation (nine respondents) comprised the major categories of replies to the question, "What makes a crew perform well together?" The corollary question, "What are the

reasons for poor crew performance?" yielded answers mostly opposite to those from the previous question: poor interpersonal relations (sixteen respondents), lazy crew members or those with poor attitudes (eleven respondents), and poor planning/supervision (four respondents).

In review, then, the HOTS construction workers placed high values on a work environment in which crew members got along well with one another; while, each performed a fair share of the work to be done. Supervisors receiving high marks were those who treated crew members fairly and who routinely recognized the hard work and skilled efforts of their subordinates. Moreover, the preferred leadership style at the job site was an unstructured approach. Rather than constantly supervising crew members' activities, good foremen -- as judged by the HOTS work force -- were those who issued instructions to crew members, then allocated to these craftsmen the flexibility and responsibility to accomplish the required tasks.

The interview responses of the project foreman indicated that, for the most part, they supported this preferred work environment described by HOTS construction worker in their answers to the questionnaires. The foremen all asserted that earning the respect of their crew members was extremely important. Additionally, the foremen were unanimous in conveying their respect for the skills, personalities, and needs of their subordinates. Each foreman

stated that he was concerned about the individual needs of his journeymen and helpers, and that he was open to worker suggestions. Three foremen agreed that all their workers took pride in their work; while, two qualified this pride as being representative of most of their crew members. Lastly, all five foremen felt that they openly commended their subordinates for a job well done; two foremen went so far as to critique their past efforts by saying that they had not shown enough appreciation to their crew members.

To evaluate these data provided by the foreman regarding their leadership style, craftsmen answers to still further interview questions were examined. Twenty-seven of thirty workers stated that they did not feel restricted by their foreman at the workplace. Fifteen respondents cited examples of their foreman adopting one or more of their work related suggestions; thirteen other workers noted that they had not yet made any suggestions to their foreman, but that he was open to suggestions from crew members. Twenty-four interviewees affirmed their belief that both their foreman and the HOTS project management were concerned about the work force as individuals.

Openly rewarding crew members for a job well done was listed by twenty-four workers as a leadership trait among project foremen. The most common methods employed by foremen to accomplish these rewards were verbal praise of crew members, the purchase of sodas for construction workers, or arrangements for workers to receive a watermelon break during the workday. Hence, it appeared

that the questionnaire responses from the construction workers at the HOTS project validated the foremen's assessment of their leadership style. Since this style was congruous with the work environment preferred by the interviewed journeymen and helpers, no obvious conclusion could be drawn concerning job site conditions as the cause of the voluntary departures of six personnel during July and August 1986.

A few attitudinal assessments of the HOTS project work force should be made before finishing this discussion about worker retention. A majority of the construction workers (twenty-five respondents) indicated that their families supported them in their pursuit of a career in the construction industry. Twenty-one workers stated that they never took the job home with them. The crew's foreman was listed by seventeen respondents as the individual at the job site whose opinion was most important. The site manager's opinion was cited as most significant by ten workers. Four crew members felt that their own opinion meant the most to them; whereas, only two individuals at the craftsmen level listed the superintendent's views as meaning the most to them. Twenty-two craftsmen indicated that they desired more information concerning how their separate craft related to the other trades at the project in contributing to the finished product: a heavy oil test station. Finally, whether or not Becon Construction Company made a profit at the HOTS project mattered to twenty-five of the respondents.

Before closing, key responses offered by the project foremen during their interviews will be highlighted. Three foremen stated that they did not take the job home with them; two others admitted to occasionally taking the job home. The opinions of the site manager (two respondents), the opinions of crew members (one respondent), and personal opinions (two respondents) were listed by the foremen as being most important at the construction site. In like manner with the craftsmen's responses, the opinion of the project superintendent was strangely absent from this list. Three of five foremen felt that management did not restrict them at the workplace; while, only two foremen perceived that management was concerned about their individual needs.

All foremen rated as important their need to know and understand job estimates, costs, and profitability information. At the same time, only one foreman stated that management informed him of such information; two others admitted to receiving bits and pieces of profitability information on a periodic basis. It mattered to all the project foremen whether or not Becon Construction Company made a profit in the HOTS construction effort. Lastly, foremen gave the following reasons why they might leave Becon to hire on with another company:

- o Better offer elsewhere (3 respondents)
- o No reason cited
- o Promises made, but not kept by management
- o Transferring poor workers to another Becon project rather than terminating these workers.

CHAPTER 4. CONCLUSIONS AND RECOMMENDATIONS

4.1 Conclusions

In keeping with the revised objectives of the study, conclusions were drawn from the analysis of the qualitative data collected at the HOTS project from January to August 1986. These conclusions were categorized as follows:

- o Factors that effect satisfactions
- o Factors that effect dissatisfactions
- o Comparison of HOTS project data with that of the pilot study

Two job satisfiers identified for the journeymen and helpers at the HOTS project were identical to those satisfactions cited by the craftsmen who participated in Dr. John D. Borcherding's pilot study.[51] Accordingly, conclusions drawn about factors which produce HOTS project satisfactions were similar to the conclusions inferred from the pilot study results.[52] First of all, feedback continually received by HOTS crew members regarding the quality and quantity of their work helped to create satisfactions gained through completing the various stages of construction at each heavy oil test station. In addition, the bringing together of civil, electrical, mechanical, and prefabrication stages of each work site to produce a functional test station week after week was inherently responsible for satisfying the work force at the HOTS project.

Still another conclusion was reached after reviewing the HOTS project data concerning a factor which gave rise to worker satisfaction, but which was not previously indicated in the pilot study. At the HOTS project, satisfaction was realized among numerous helpers because of a work environment in which inexperienced, unskilled laborers were afforded an opportunity to learn a trade. For most of these helpers, the construction skills acquired while in the employ of Becon Construction Company represented their commencement of a career in the construction industry. Indeed, fourteen of these helpers were between the ages of eighteen and twenty-three years old. The opportunity to begin a new profession was an experience that these helpers did not take lightly. Moreover, this opportunity was a source of satisfaction important enough to be mentioned by thirteen of twenty-three helpers during their interviews at the project site. Consequently, the time that these helpers spent with Becon at the HOTS project was an investment, of sorts, in their future as skilled craftsmen.

For the most part, the job satisfactions noted by the five HOTS project foremen mirrored those identified in the pilot study.[53] Once again, the pilot study's conclusions regarding factors producing field supervisors' satisfactions applied as well to the HOTS project.[54] Therefore, the delegation by HOTS project management to field supervisors of the responsibility for the quality and quantity of completed work induced satisfactions in these foremen. In short, the HOTS project foremen were satisfied

through the challenge of executing construction activities so as to achieve the timely, high quality completion of succeeding heavy oil test stations. Furthermore, the continuous flow of quality control and scheduling information to HOTS foremen by project management brought about the job satisfiers of maintaining schedules and performing good workmanship.

One final job satisfaction, unique to HOTS project foremen in comparison to those of the pilot study, indicated that the training demands placed on HOTS field supervisors because of inexperienced crew members were, in fact, welcomed by these supervisors. In other words, the experience of teaching trade skills to the younger, less knowledgeable helpers among the crews was a rewarding one for HOTS project foremen. In addition to the challenge of running the job, each field supervisor at the HOTS project assumed the challenge of developing new workers into productive craftsmen. Thus, it appeared that the composition of the HOTS work force -- in particular, the number of helpers per crew who required training -- was a notable factor in producing satisfactions for project foremen in their requisite role as a teacher on the job site.

In like manner with the identified satisfactions of the HOTS journeymen and helpers, two job dissatisfiers of HOTS construction crew members were similar to those highlighted in the pilot study.[55] As a result, conclusions drawn about factors causing these two HOTS work force dissatisfactions were comparable to the inferences made concerning the pilot study's factors.[56] Crew

members at the HOTS project who failed to perform their fair share of the crew's work load caused the other journeymen and helpers on the crew to accomplish what was perceived to be an inordinate amount of work at the job site. This work load imbalance, then, developed in the overworked craftsmen dissatisfactions. At the same time, those workers at the HOTS project who demonstrated poor attitudes about their work or who executed sloppy construction created a feeling of disgust among the workers who were genuinely concerned about producing high quality construction. This existence of negative feelings toward crew members with poor attitudes gave rise to dissatisfactions in the dedicated craftsmen at the HOTS project.

Also noted as a source of dissatisfaction among HOTS workers was the wasting of time or the lack of work. Obviously, this dissatisfier was a direct result of the material and scheduling constraints under which the HOTS project operated. More importantly, the fact that project management knew these constraints existed placed a heavy burden on managerial staff and field supervision to carefully plan and manage the construction crews' efforts in order to prevent the occurrence of slack time on the job site. Therefore, the inability of HOTS management to adhere to an efficient, well coordinated project execution schedule -- one which minimized delays caused by the imposed material and design information constraints --

was a major contributing factor to the degree of worker dissatisfaction created by the lack of work at the job site.

Contrary to the foremen dissatisfiers identified in the pilot study data, the job dissatisfactions of HOTS field supervisors were mainly opposites of the satisfiers cited by these foremen. For obvious reasons, no mention was made by HOTS project foremen about dissatisfactions experienced as a result of union labor problems; whereas, union related concerns proved to be the source of three of four foremen dissatisfactions derived from the pilot study's data.[57] Hence, the factors creating the job dissatisfiers among HOTS field supervision centered more on the amount of confidence that management placed in each foreman, and on the degree of responsibility that management assigned the foremen to complete the construction stages of each test station on time, under budget, and in the highest quality.

A third set of conclusions were made after evaluating the qualitative data from the HOTS project. These conclusions dealt specifically with the contrast of data collected from HOTS project journeymen and helpers with data gathered from predominantly union craftsmen interviewed as part of Dr. John D. Borcherding's pilot study. First, a job satisfier having to do with learning trade skills existed among the helpers of the open shop work force at the HOTS project; whereas, no such job satisfaction was demonstrated by the union apprentices interviewed in the pilot study.[58] Union apprenticeship programs were structured such that apprentices

underwent some training in craft skills prior to their hiring on at a construction site. On the other hand, the first construction job for many open shop helpers also represented their initial training and exposure to trade tecnniques in the construction industry. The conclusion reached, then, was this: that an additional source of job satisfaction for construction helpers employed by an open shop contractor was the opportunity for these helpers to learn new trade skills.

A significant job dissatisfier for the journeyman and apprentices interviewed during the pilot study was the work itself, when it was repetitive in nature.[59] Yet, the work force at the HOTS project was engaged in just that type of work: the repetitive execution of construction tasks to produce ninety-two essentially identical heavy oil test stations. Why, then, was repetition not cited as a significant source of dissatisfaction by the HOTS project journeymen and helpers? One possible conclusion was that for a predominantly young, inexperienced work force, repetitious construction work was not as significant a job dissatisfaction as were repetitive tasks for a seasoned, skilled group of journeymen. In other words, the workers of an open shop contractor -- comprising a larger percentage of helpers than journeymen -- experienced considerably less job dissatisfaction from construction that was repetitive in nature than did the journeymen and apprentices of union contractors, whose work force composition was mandated by union rules and was particularly lacking in numbers of apprentices. Finally, the

presence within the HOTS workforce of a dissatisfaction caused by the lack of work tended to support the pilot study's basic contention that construction work, when well planned and efficiently executed so that workers were productive, was itself satisfying to the work force.[60] As evidenced by data from the HOTS project, the absence of tasks for the work force to productively accomplish lead to dissatisfactions among some crew members.

4.2 Recommendations

Recommendations to enhance the retention of the HOTS work force were formulated based on the conclusions regarding factors that effected satisfactions and dissatisfactions in the project foremen, journeymen, and helpers. Moreover, numerous issues brought out in the analysis of worker retention in Section 3.11 were also considered. For example, the fact that most HOTS project personnel enjoyed significant family support of their profession was felt to be important in recommending ways to improve worker retention. Also of value in devising recommendations was the desire by a majority of workers at the site to know more about how individual trades integrated with each other to produce a completed heavy oil test station. Another notable point was the fact that most crew members perceived company social functions as providing additional job satisfactions.

In reviewing the big picture at Becon's HOTS project, it appeared that the field supervisors were generally the right men

for the job. These five foremen constituted a group of people-oriented, highly skilled leaders who created a working environment which was preferred by the workers. Journeymen and helpers, alike, were challenged by their foremen with the responsibility for producing timely, high quality construction. Furthermore, the HOTS foremen allowed these workers the flexibility to make and learn from mistakes on the job site. Despite the fact that turnover of journeymen and helpers was relatively high during the study period, this same group of foremen capably orchestrated construction operations to achieve continual gains in crew productivity.

Therefore, any recommendations concerning the retention of the HOTS work force had to address the retention of the key players in the project's success to date: the foremen. Of particular interest were the foremen's questionnaire responses in which they expressed the desire to receive profitability, estimating, and cost information. Additionally, three of five foremen cited better money elsewhere as a possible reason for leaving Becon's HOTS project.

With these considerations in mind, then, the following recommendations were formulated to enhance the retention of foremen, journeymen, and helpers at Becon's HOTS project for the duration of the planned construction:

- Develop and institute at the project site an orientation briefing (slide show) for newly hired employees. Give this briefing to currently employed helpers as schedules permit.

- Continue to schedule periodic project social functions. Make a point to include the family members of project personnel in these events. One specific suggestion would be to arrange for a bus to transport family members from distant Bakersfield (where most of the project workers live) to a picnic at the project site and back. Include as part of this picnic a visit to a completed HOTS so that families can witness first hand what the construction workers are building at the job site.

- Begin formal exit interviews for all employees who voluntarily quit the project. Attempt to determine during these interviews exactly why employees leave Becon's HOTS project.

- Continue to emphasize the use of praise by management and foremen to recognize the efforts of construction crew members at the HOTS project. Do not be concerned about overdoing it; too little praise is far worse than too much praise in terms of enhancing worker satisfactions and reducing dissatisfactions.

- In keeping with the previous recommendation, try developing and instituting some sort of formal recognition program such as "crew member of the week/month" or "construction crew of the week/month." Solicit ideas from the superintendent and the foremen when developing the program and include their evaluation as part of the criteria for selecting a winner each week/month. Award a prize to the winners: belt buckle, cap, etc.

- Continue the implementation of the HOTS project suggestion awards program.

- Continue the implementation of the HOTS project educational assistance program which affords construction craftsmen financial support of up to $250 per year to complete courses at accredited colleges, universities, trade schools, and vocational schools.

- Emphasize the foremen's roles as trainers for inexperienced crew members. Encourage foremen to fill slack time in the project schedule with training in construction methods and techniques. Journeymen may also be enlisted by foremen to train helpers during such periods. Have each foreman develop a list of training topics

(required trade skills) for use in organizing training on the job site. Thereupon, foremen must be prepared to train crew members in any one of these topics on a moment's notice; i.e., whenever slack time in the project schedule occurs. Consequently, crew members will receive the benefit of training in new trade skills; at the same time, they will avoid experiencing boredom at the job site caused by the lack of work during slack periods.

- Have each foreman develop a list of "pet" projects or tasks that need to be accomplished around the workplace; i.e., sharpening of tools, cleaning out storage areas, painting equipment, etc. Then, in the event of slack periods in the construction schedule, foremen should accomplish these tasks as appropriate. Once again, crew members avoid experiencing boredom because of the lack of work during slack periods; while, handy projects are completed to enhance the working environment at the HOTS work site. In particular, the workers experiencing the most slack time on the job were those in the prefabrication and yard crews. Yet, efforts to initiate a comprehensive supply parts inventory program in the project storage area were repeatedly stalled because of the lack of man power to categorize and arrange countless parts and supplies. An obvious solution to get this program off the ground would be to employ the man power of yard or prefabrication crew members -- already located in the project storage area -- during their slack periods.

- Institute some form of incentive or bonus pay program, at a minimum, for the HOTS project foremen. Although the project's financial constraints may prohibit the implementation of an incentive or bonus pay program for the entire project work force, the wages of the five project foremen deserve special consideration for such an incentive or bonus plan. Such a pay plan for the foremen should help to ensure their retention for the project's duration, thus enhancing the probability that HOTS construction will continue to be successfully orchestrated by this competent crew of field supervisors.

- Lastly, urge the HOTS superintendent to assume the role of project innovator. While the field supervisors are routinely occupied with the demands of daily construction activities, the superintendent is basically free of such pressures on the HOTS project, a relatively small scale construction operation. Consequently, the

superintendent is in a position to devise, research, and initiate at the job site various improvements to the working conditions. Such improvements could include the procurement of nice-to-have tools and equipment which enable craftsmen to work more efficiently and quickly. Moreover, a possible spin-off from the superintendent's new role as project innovator might be his greater involvement in daily construction operations. In other words, the superintendent's exposure and influence on the project foremen and craftsmen could increase. As evidenced by the results of the questionnaire interviews, the superintendent's present impact at the crew level is strangely less than significant.

APPENDIX I

QUESTIONNAIRES

This appendix contains blank copies of the questionnaires on which were recorded the responses of Becon Construction Company personnel during interviews at the HOTS project. The three questionnaires correspond to the number of hierarchical levels in the organization of the HOTS construction work force: journeyman and helper, foreman, and superintendent/field management staff.

BECON CONSTRUCTION COMPANY, INC.
SHELL CALIFORNIA PRODUCTION, INC.
HEAVY OIL TEST STATIONS
BAKERSFIELD, CALIFORNIA
JOB 1264

INTERVIEW QUESTIONNAIRE TO HELPERS AND JOURNEYMEN

1. What is your job?

2. Why did you become a ______________________?

3. What gives you the most job satisfaction?

4. What gives you the most job dissatisfaction?

5. How enjoyable is your work?

6. If you could do it all over again, would you chose this profession?

7. Does society respect your talents and skills?

8. Has the quality of work improved or declined during your career (explain)?

9. Do you take the job home with you?

10. How does your family feel about your profession?

11. What could your foreman do to really upset you or frustrate you?

12. What could management do to really upset you or frustrate you?

FIGURE 20

Journeyman and Helper Questionnaire

13. Whose opinion of your job means the most to you?

14. How should a good foreman manage a crew?

15. What makes a crew perform well together?

16. What are the reasons for poor crew performance?

17. Does your foreman restrict you in your work capacity here at the jobsite (explain)?

18. Has your foreman acted upon your suggestions dealing with construction methods, safety, etc. (explain)?

19. Would you like to participate more in decision-making at the job site (work methods, safety, choice of work and crew members)?

20. Would you like additional information on how your work relates to the other trades and how it contributes to the project?

21. Is your foreman concerned about you as a person?

22. Is management concerned about you as a person?

23. Should your foreman or management be concerned about your individual needs (explain)?

24. Does your foreman openly reward you or his crew for a job well done? (If "yes," how; if "no," should he?)

FIGURE 20 (CONT)

Journeyman and Helper Questionnaire

25. Is the respect of your fellow workmen important to you? (If yes, how is it gained?)

26. Other than money, why is your work important to you?

27. What do you like about your trade now? 10 years ago?

28. What do you dislike about your trade now? 10 years ago?

29. Is there anything management could do that would make your job more satisfying?

30. Do you think management is doing its best to insure your safety? (If not, what can be done?)

31. Can you think of a particular instance on this job when management handled a human relations problem poorly? Or well?

32. Do you think company social functions provide additional job satisfaction?

33. Would you prefer a crew bonus or a recognition dinner as a reward for high performance?

34. Does it matter to you if Becon Construction makes money on this job?

35. Does management give you information about the profitability of this job?

36. Do you plan to stay on for the duration of this job (projected completion in November 1987)?

FIGURE 20 (CONT)

Journeyman and Helper Questionnaire

BECON CONSTRUCTION COMPANY, INC.
SHELL CALIFORNIA PRODUCTION, INC.
HEAVY OIL TEST STATIONS
BAKERSFIELD, CALIFORNIA
JOB 1264

INTERVIEW QUESTIONNAIRE TO GENERAL FOREMEN

1. What do you perceive your job to be?

2. Why did you become a foreman?

3. Why do you remain a foreman?

4. What gives you the most job satisfaction?

5. What gives you the most job dissatisfaction?

6. Why are you different from a journeyman?

7. How would you evaluate a journeyman's skill level as compared to a foreman's skill level?

8. Does the company pay you enough for your efforts? (Explain) If answer is "no", ask, "what are you worth?".

9. What could management do to really upset you or frustrate you?

10. Has the quality of workmanship within your trade improved or declined during your career?

11. What are the reasons why you would leave this company?

FIGURE 21

Foreman Questionnaire

12. Do you take the job home with you?

13. How enjoyable is your work?

14. If you could do it all over again, would you choose this profession?

15. Does society respect your talents and skill?

16. Whose opinion of your job means the most to you?

17. Other than money, why is work important to you?

18. How does your family feel about you being a foreman?

19. Does management restrict you in your work capacity? (Explain)

20. Has management acted upon your suggestions dealing with construction methods, safety, manpower allocation, etc.? (Explain and give examples.)

21. Is management concerned about you as a person?

22. Should management be concerned about your individual needs?

23. Is it important to you to know about and understand job estimates, costs, and profitability?

24. Does management inform you of estimates? costs? profitability?

FIGURE 21 (CONT)

Foreman Questionnaire

25. Does it matter to you if Becon Construction makes money on this job?

26. Does management openly reward you or your men for a job well done? (If "yes", now; if "no", should they?)

27. Does management regularly hold job progress meetings with you?

28. Do you actively participate in these meetings?

29. How effective are these meetings? Why?

30. Who establishes job policy (coffee breaks, crew balance, material ordering, etc.)?

31. Has management ever invited you to help establish these policies?

32. How many men are you responsible for?

33. How many men should you be responsible for?

34. Is the respect of your men important to you? Why?

35. Do you respect the skill, personality, and needs of those that work for you?

36. As a foreman, are you concerned about the individual needs of your men?

37. How much authority (methods of construction, etc.) do you delegate to your crew?

38. Are you open for worker suggestions?

FIGURE 21 (CONT)

Foreman Questionnaire

39. Do you as a foreman openly commend or show appreciation for a job well done?

40. Do your workers take pride in their work?

41. Do you plan to stay on for the duration of this job (projected completion in November 1987)?

FIGURE 21 (CONT)

Foreman Questionnaire

BECON CONSTRUCTION COMPANY, INC.
SHELL CALIFORNIA PRODUCTION, INC.
HEAVY OIL TEST STATIONS
BAKERSFIELD, CALIFORNIA
JOB 1264

INTERVIEW QUESTIONNAIRE TO SUPERINTENDENT AND SITE MANAGER

1. What do you perceive your job to be?

2. What gives you the most job satisfaction?

3. What gives you the most job dissatisfaction?

4. Do you take the job home with you?

5. How enjoyable is your work?

6. Whose opinion of your job means the most to you?

7. Other than money, why is work important to you.

8. What do you consider a foreman's job to be?

9. What motivates a man to become a foreman?

10. What makes a foreman different from a journeyman?

11. What is the procedure your company uses to select foremen?

FIGURE 22

Superintendent/Site Manager Questionnaire

12. Does your company have a formal training program for foremen?

13. How does your company assist the foreman to assume the role of company representative on the job?

14. How do you evaluate the performance of your foremen?

15. What personal characteristics or attributes differentiates productive foremen from less productive foremen?

16. Does management encourage and act on suggestions from the field? If yes, example.

17. How does your company get the men in the field to make suggestions?

18. Is it the responsibility of management to be concerned about the individual or personal welfare of those in the field? If yes, how is this concern conveyed to the field?

19. To what extent should foremen be informed of job estimates, costs, and profitability?

20. How does management reward the foremen and journeymen for a job well done? Example.

21. Does management periodically evaluate the performance of journeymen and foremen that continue to work for the company?

22. To what extent should foremen be encouraged to help establish job policy?

23. How does your company evaluate crew efficiency?

FIGURE 22 (CONT)

Superintendent/Site Manager Questionnaire

24. Is the respect of your foremen and journeymen important to you?

25. Is it necessary for a successful job?

26. Has the quality of workmanship among the trades improved or declined during your career? Why?

27. To what degree is the foreman responsible for the success of the job? Explain.

28. Should a general foreman be expected to put in time with the tools on a job? What about crew foremen?

29. What is the foreman's most important job?

30. What is the general policy of your company regarding retention of foremen on payrolls between jobs?

31. Is the foreman concerned about job profitability? Journeymen? If yes, how does your company achieve this concern? If no, do you feel that the foreman should be concerned? And if so, how could your company achieve this concern?

32. Do you feel that there is good communication between management and the field (vertical, downward)? If yes, how is this accomplished?

33. Do you feel that there is good communication between the field and management (vertical, upward)?

34. Do you feel that company sponsored parties and activities, i.e., picnics, dinners, bowling teams, etc., increase productivity and job satisfaction?

35. Do you plan to stay on for the duration of this job (projected completion in November 1987)?

FIGURE 22 (CONT)

Superintendent/Site Manager Questionnaire

APPENDIX II

Monthly Manpower & Absentee Data

This appendix consists of monthly summaries of the daily manning levels and absentee rates at Becon Construction Company's HOTS project from January to August 1986. These data include only those construction personnel at the foreman level and below. In other words, Becon's project management staff members - to include the project superintendent - are excluded from the listed data.

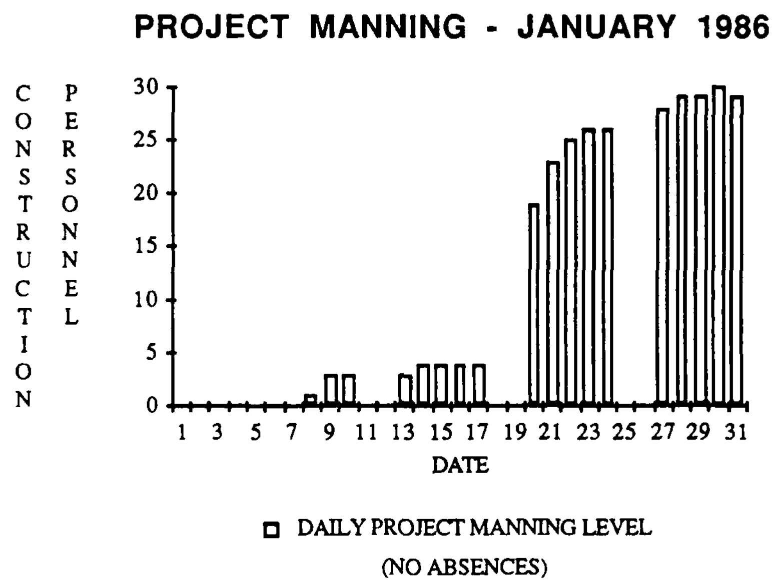
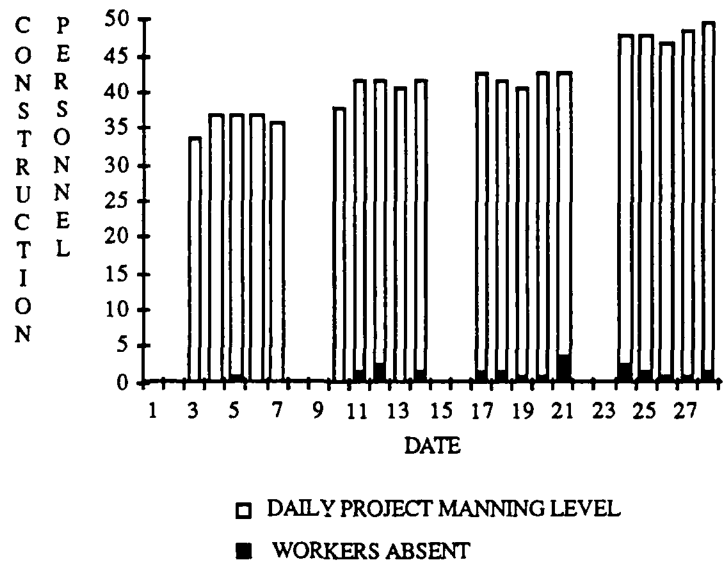


FIGURE 23

Manpower/Absentee Data: January 1986

MANNING/ABSENTEEISM - FEBRUARY 1986



ABSENTEEISM AS % OF WORK FORCE FEBRUARY 1986

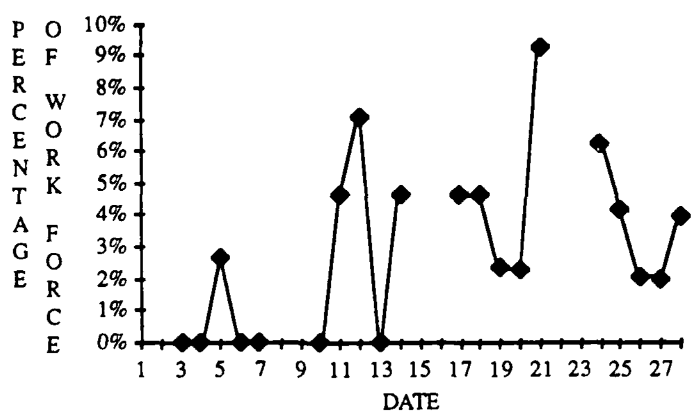


FIGURE 24

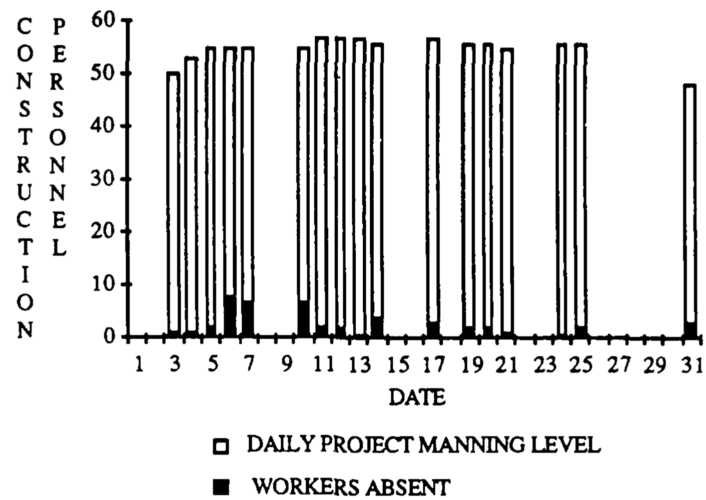
Manpower/Absentee Data: February 1986

Date:	January 1986 Manning Level		January 1986 Absentees	February 1986 Manning Level		February 1986 Absentees
1	-		-	X	(Sat)	X
2	-		-	X	(Sun)	X
3	-		-	34		0
4	-		-	37		0
5	-		-	37		1
6	-		-	37		0
7	-		-	36		0
8	1		0	X	(Sat)	X
9	3		0	X	(Sun)	X
10	3		0	38		0
11	X	(Sat)	X	42		2
12	X	(Sun)	X	42		3
13	3		0	41		0
14	4		0	42		2
15	4		0	X	(Sat)	X
16	4		0	X	(Sun)	X
17	4		0	43		2
18	X	(Sat)	X	42		2
19	X	(Sun)	X	41		1
20	19		0	43		1
21	23		0	43		4
22	25		0	X	(Sat)	X
23	26		0	X	(Sun)	X
24	26		0	48		3
25	X	(Sat)	X	48		2
26	X	(Sun)	X	47		1
27	28		0	49		1
28	29		0	50		2
29	29		0	X		X
30	30		0	X		X
31	29		0	X		X

TABLE 13

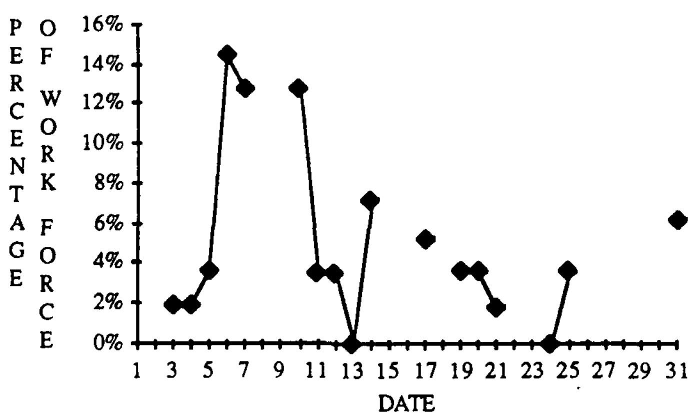
Manpower/Absentee Data: January-February 1986

MANNING/ABSENTEEISM - MARCH 1986



NO DATA AVAILABLE FOR MARCH 18, 26, 27, & 28 1986

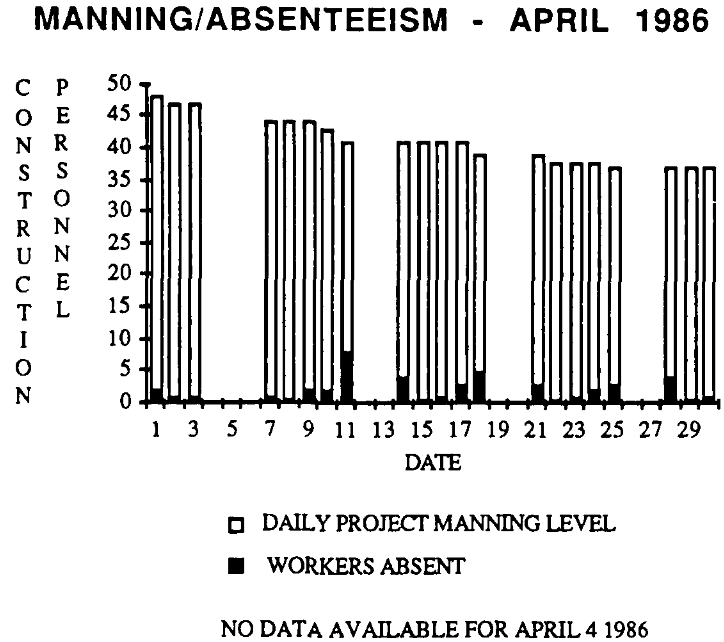
ABSENTEEISM AS % OF WORK FORCE MARCH 1986



NO DATA AVAILABLE FOR MARCH 18, 26, 27, & 28 1986

FIGURE 25

Manpower/Absentee Data: March 1986



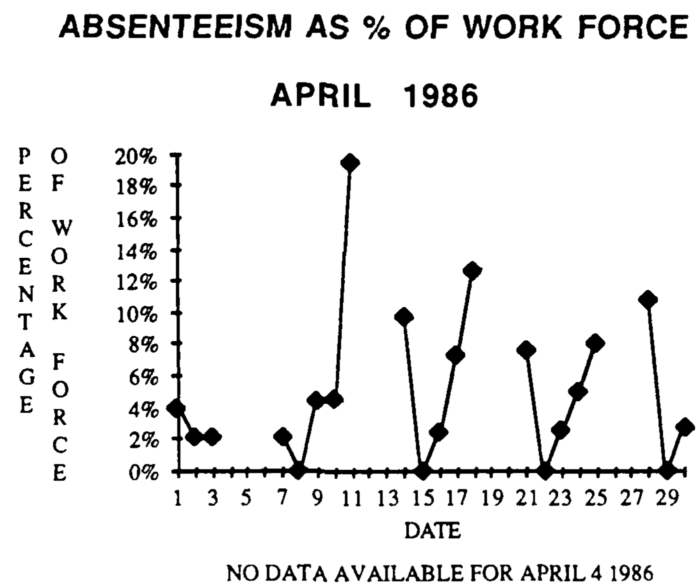


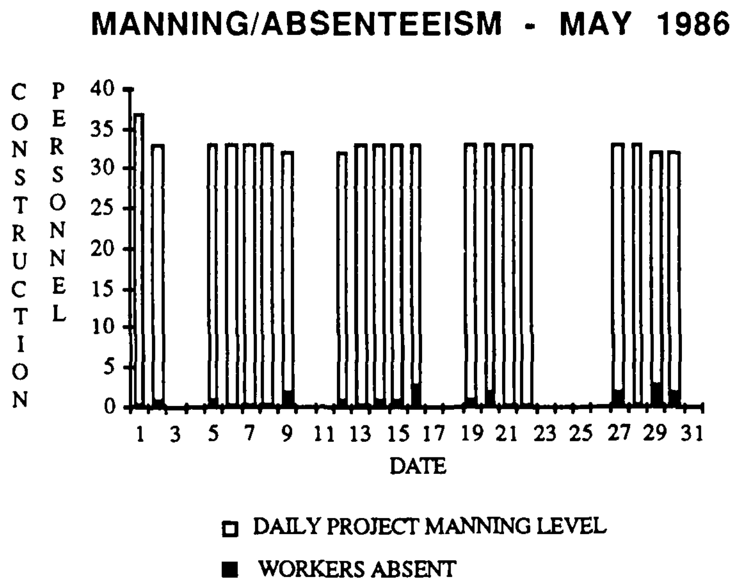
FIGURE 26

Manpower/Absentee Data: April 1986

Date:	March 1986 Manning Level		March 1986 Absentees	April 1986 Manning Level		April 1986 Absentees
1	X	(Sat)	X	48		2
2	X	(Sun)	X	47		1
3	50		1	47		1
4	53		1	46		No Data
5	55		2	X	(Sat)	X
6	55		8	X	(Sun)	X
7	55		7	44		1
8	X	(Sat)	X	44		0
9	X	(Sun)	X	44		2
10	55		7	43		2
11	57		2	41		8
12	57		2	X	(Sat)	X
13	57		0	X	(Sun)	X
14	56		4	41		4
15	X	(Sat)	X	41		0
16	X	(Sun)	X	41		1
17	57		3	41		3
18	56		No Data	39		5
19	56		2	X	(Sat)	X
20	56		2	X	(Sun)	X
21	55		1	39		3
22	X	(Sat)	X	38		0
23	X	(Sun)	X	38		1
24	56		0	38		2
25	56		2	37		3
26	56		No Data	X	(Sat)	X
27	48		No Data	X	(Sun)	X
28	48		No Data	37		4
29	X	(Sat)	X	37		0
30	X	(Sun)	X	37		1
31	48		3	X		X

TABLE 14

Manpower/Absentee Data: March-April 1986



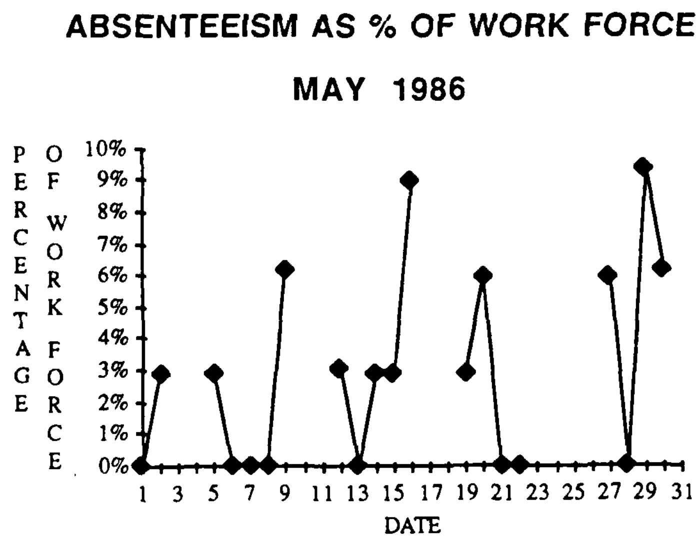
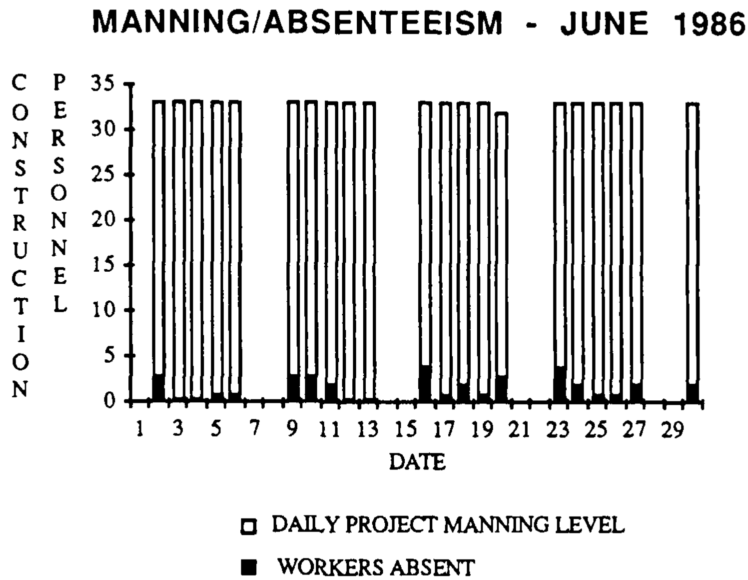


FIGURE 27

Manpower/Absentee Data: May 1986



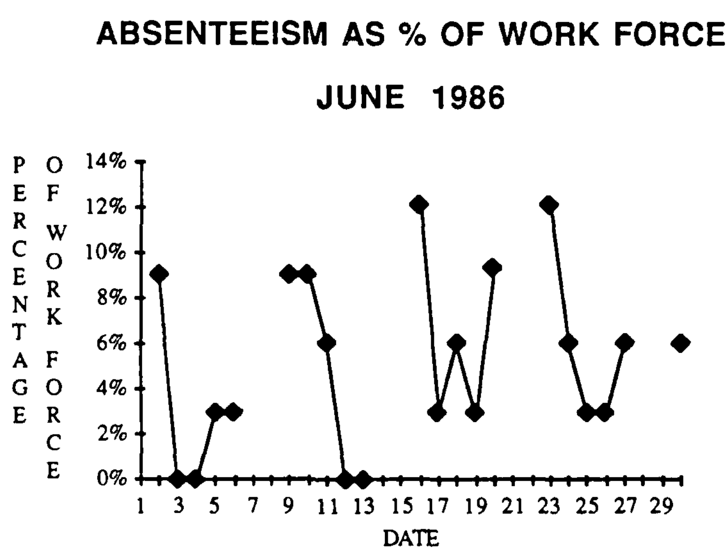


FIGURE 28

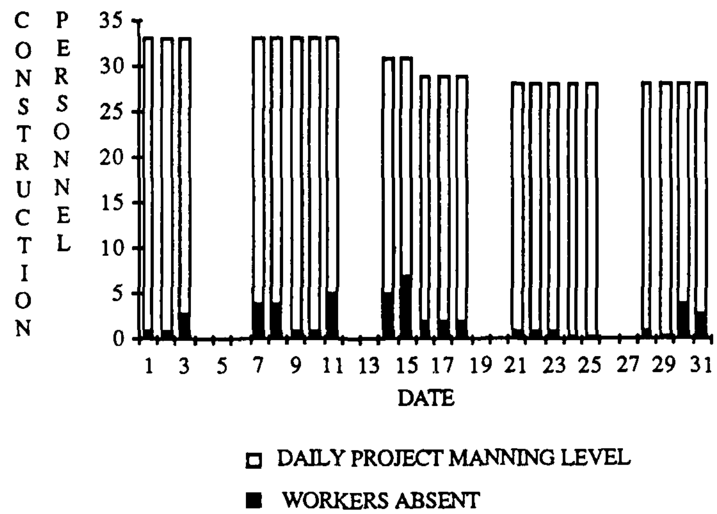
Manpower/Absentee Data: June 1986

Date:	May 1986 Manning Level		Absentees	June 1986 Manning Level		Absentees
1	37		0	X	(Sun)	X
2	33		1	33		3
3	X	(Sat)	X	33		0
4	X	(Sun)	X	33		0
5	33		1	33		1
6	33		0	33		1
7	33		0	X	(Sat)	X
8	33		0	X	(Sun)	X
9	32		2	33		3
10	X	(Sat)	X	33		3
11	X	(Sun)	X	33		2
12	32		1	33		0
13	33		0	33		0
14	33		1	X	(Sat)	X
15	33		1	X	(Sun)	X
16	33		3	33		4
17	X	(Sat)	X	33		1
18	X	(Sun)	X	33		2
19	33		1	33		1
20	33		2	32		3
21	33		0	X	(Sat)	X
22	33		0	X	(Sun)	X
23	X	(Holiday)	X	33		4
24	X	(Sat)	X	33		2
25	X	(Sun)	X	33		1
26	X	(Holiday)	X	33		1
27	33		2	33		2
28	33		0	X	(Sat)	X
29	32		3	X	(Sun)	X
30	32		2	33		2
31	X	(Sat)	X	X		X

TABLE 15

Manpower/Absentee Data: May-June 1986

MANNING/ABSENTEEISM - JULY 1986



ABSENTEEISM AS % OF WORK FORCE

JULY 1986

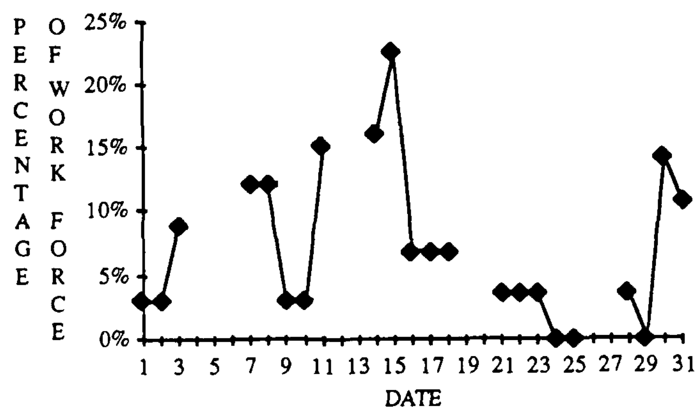
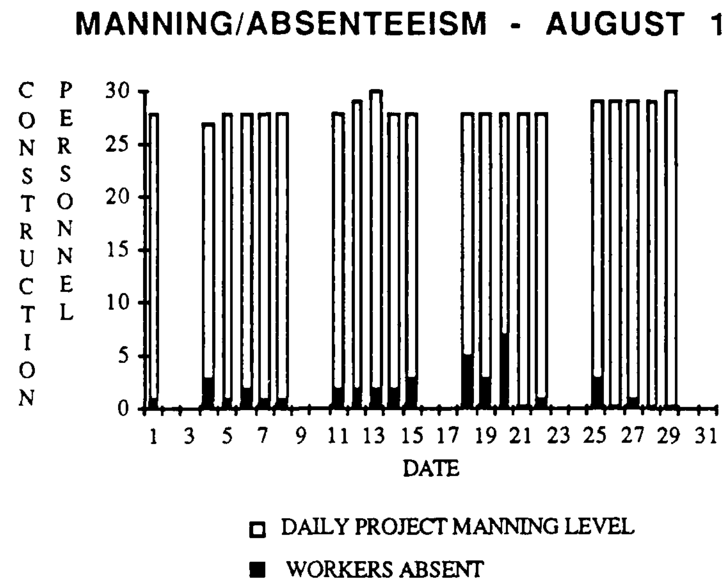


FIGURE 29

Manpower/Absentee Data: July 1986



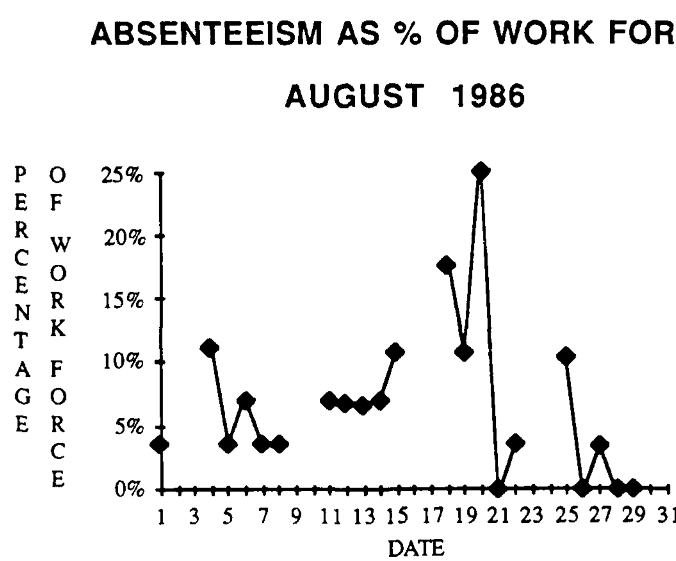


FIGURE 30

Manpower/Absentee Data: August 1986

Date:	July 1986 Manning Level		July 1986 Absentees	August 1986 Manning Level		August 1986 Absentees
1	33		1	28		1
2	33		1	X	(Sat)	X
3	33		3	X	(Sun)	X
4	X	(Holiday)	X	27		3
5	X	(Sat)	X	28		1
6	X	(Sun)	X	28		2
7	33		4	28		1
8	33		4	28		1
9	33		1	X	(Sat)	X
10	33		1	X	(Sun)	X
11	33		5	28		2
12	X	(Sat)	X	29		2
13	X	(Sun)	X	30		2
14	31		5	28		2
15	31		7	28		3
16	29		2	X	(Sat)	X
17	29		2	X	(Sun)	X
18	29		2	28		5
19	X	(Sat)	X	28		3
20	X	(Sun)	X	28		7
21	28		1	28		0
22	28		1	28		1
23	28		1	X	(Sat)	X
24	28		0	X	(Sun)	X
25	28		0	29		3
26	X	(Sat)	X	29		0
27	X	(Sun)	X	29		1
28	28		1	29		0
29	28		0	30		0
30	28		4	X	(Sat)	X
31	28		3	X	(Sun)	X

TABLE 16

Manpower/Absentee Data: July-August 1986

APPENDIX III

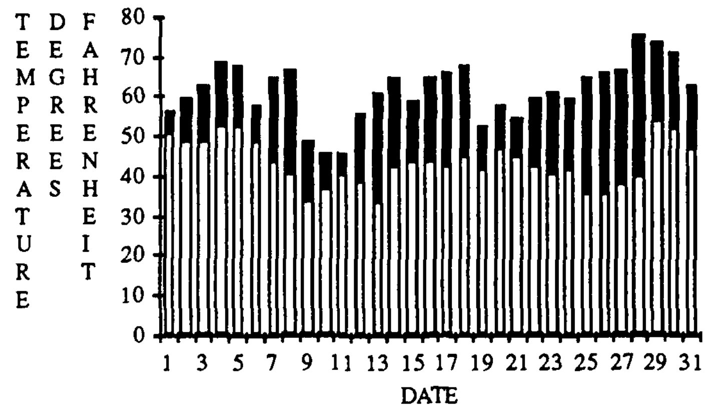
Appendix III displays monthly summaries of the daily high and low temperatures encountered at the Belridge Oil Field, site of Becon Construction Company's HOTS project, from January to August 1986. The average monthly temperature and the total monthly rainfall experienced at the job site during this period are listed in Table 17, below:

Month	Average Monthly Temperature	Total Monthly Rainfall
January 1986	52.8°F	1.12 inches
February 1986	54.7°F	0.80 inches
March 1986	59.3°F	1.95 inches
April 1986	61.1°F	0.24 inches
May 1986	69.7°F	0.02 inches
June 1986	77.9°F	0.0 inches
July 1986	80.7°F	trace
August 1986	83.7°F	trace

TABLE 17

Average Monthly Temperature and Total Monthly Rainfall: January-August 1986

TEMPERATURE RANGES - JANUARY 1986



TEMPERATURE RANGES - FEBRUARY 1986

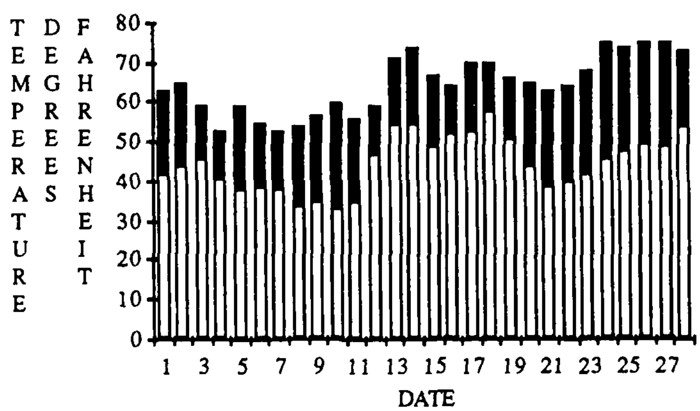
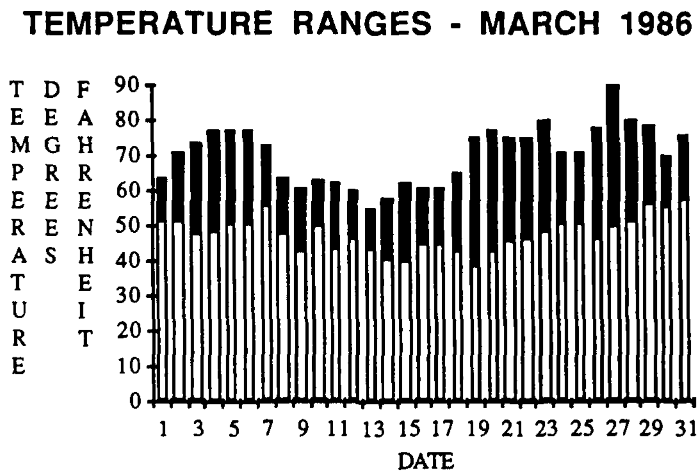


FIGURE 31

Temperature Ranges: January-February 1986



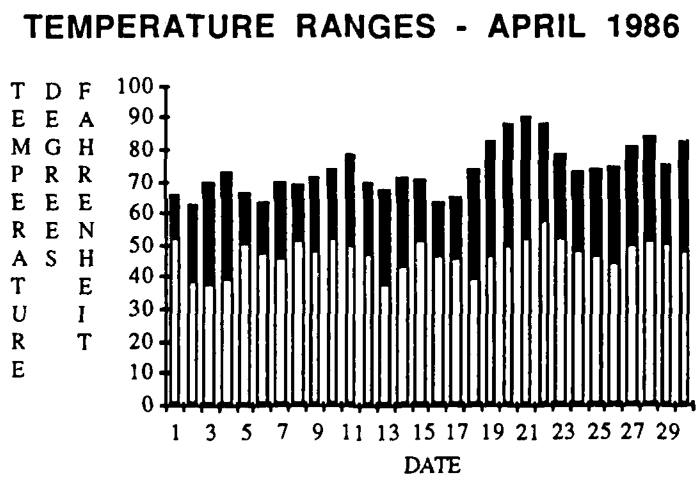
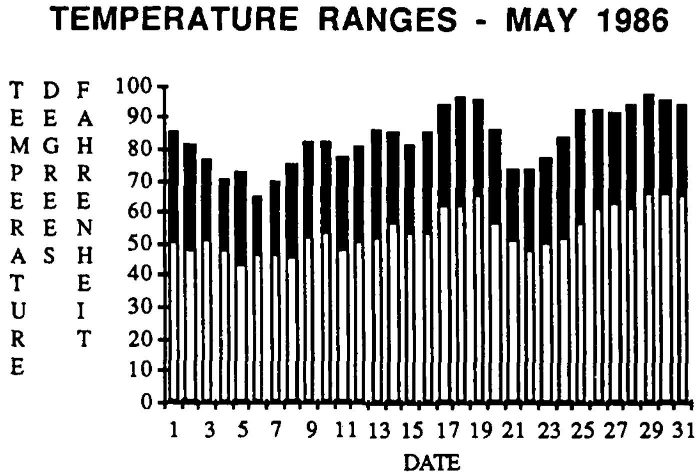


FIGURE 32

Temperature Ranges: March-April 1986



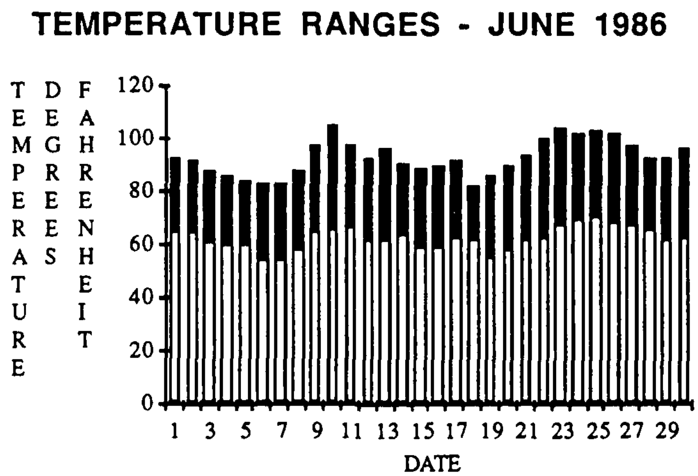
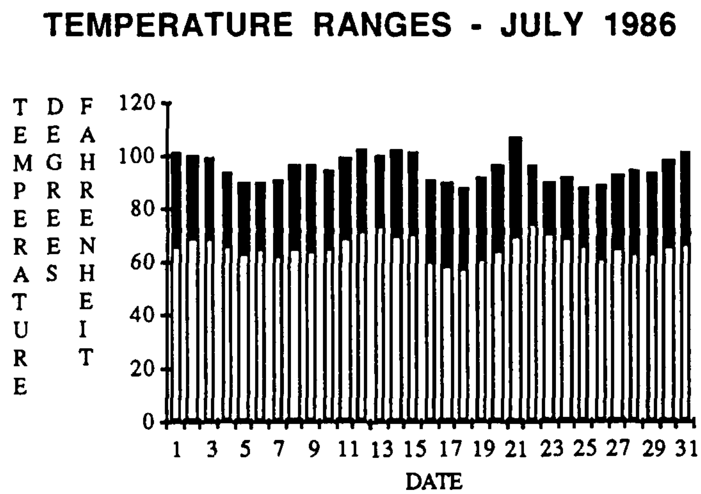


FIGURE 33

Temperature Ranges: May-June 1986



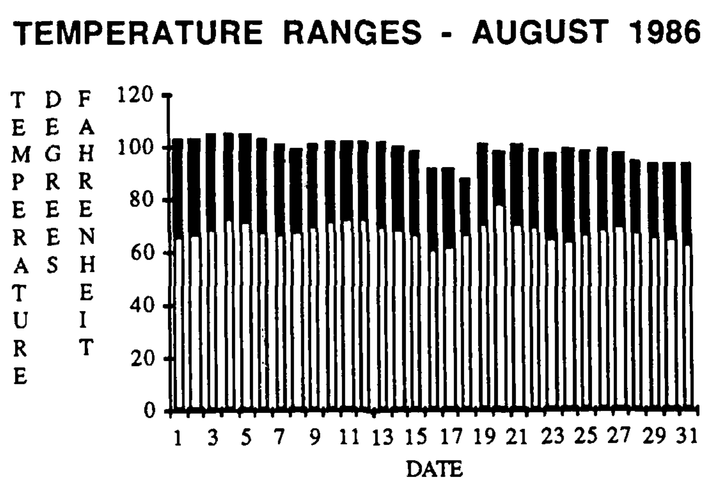


FIGURE 34

Temperature Ranges: July-August 1986

ENDNOTES

[1]Marvin Gates and Amerigo Scarpa, "Learning and Experience Curves," Journal of the Construction Division, ASCE, Vol 98 (March 1972), p. 80.

[2]T. P. Wright, "Factors Affecting the Cost of Airplanes," Journal of Aeronautical Sciences, (February 1936), p. 124.

[3]Randolph H. Thomas, Learning Curve Research at the Pennsylvania State University (State College, Pennsylvania: Pennsylvania State University, 1985), p. 4.

[4]Thomas, p. 7.

[5]This summary of the two studies dealing with the learning effect on the construction industry was extracted from Randolph H. Thomas's detailed review of these two studies in Learning Curve Research at the Pennsylavania State University (State College, Pennsylvania: Pennsylvania State University, 1985) pp. 5-7.

[6]Thomas, p. 16.

[7]Summary of Randolph H. Thomas's discussion concerning the need for accurate forecasting models in Learning Curve Research at the Pennsylvania State University (State College, Pennsylvania: Pennsylvania State University, 1985) pp. 1-4.

[8]Thomas, p. 16.

[9]These characteristics of most small to medium-sized construction projects were summarized from John D. Borcherding's discussion of both small and large scale construction projects in "Applying Behavioral Research Findings on Construction Projects," Project Management Institute Quarterly, (September 1976), pp. 9-13.

[10]The second Becon construction project was located on the periphery of the Belridge Oil Field; therefore, SCPI management allowed Becon's workers there to operate under a slightly more flexible schedule.

[11]U.S. Department of Commerce, Local Climatological Data, 1983, Bakersfield, California, National Oceanic and Atmospheric Administration Publication, pp. 1-2.

[12]Stephen Koepp, "Cheap Oil!" Time, Vol 127, No. 15 (14 April 1986), p. 62.

ENDNOTES

[13]Borcherding, "Applying Behavioral Research Findings on Construction Projects," p. 11.

[14]Borcherding, Effective Utilization of Manpower in Construction (Washington, D.C.: National Electrical Contractors Association, Inc., 1975), p.26.

[15]Frederick Herzberg, "One More Time: How Do You Motivate Employees?" Harvard Business Review, Vol 46, No 1, (January-February 1968), pp. 58-59.

[16]Borcherding, Effective Utilization of Manpower in Construction, p. 20.

[17]Borcherding, Effective Utilization of Manpower in Construction, p. 26.

[18]Henry W. Parker and Clarkson H. Oglesby, Methods Improvement for Construction Managers (New York: McGraw-Hill Book Company, 1972), pp. 50-51.

[19]This discussion of the reasons for viewing photographic recordings of construction activities was summarized from Parker and Oglesby, pp. 78-79.

[20]Parker and Oglesby, p.78

[21]Eric T. Mogren, "Pilot Study: The Effect of Scheduled Overtime and Shift Schedule on Construction Craft Productivity" (unpublished M.S. thesis, University of Texas at Austin, 1984).

[22]Mogren, p.10.

[23]Mogren, pp. 10-11.

[24]Borcherding, Effective Utilization of Manpower in Construction, p. 10.

[25]Borcherding, Effective Utilization of Manpower in Construction, pp. 236-245.

[26]Borcherding, Effective Utilization of Manpower in Construction, pp. 11-12.

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[27]Borcherding, Effective Utilization of Manpower in Construction, pp. 10-11.

[28]Borcherding, Effective Utilization of Manpower in Construction, pp. 13-16.

[29]Borcherding, Effective Utilization of Manpower in Construction, p. 14.

[30]Borcherding, Effective Utilization of Manpower in Construction, pp. 13-14.

[31]Borcherding, Effective Utilization of Manpower in Construction, p. 13.

[32]Borcherding, Effective Utilization of Manpower in Construction, p. 13.

[33]Borcherding, Effective Utilization of Manpower in Construction, p. 13.

[34]John D. Borcherding, "Work Sampling," (Unpublished report, University of Texas at Austin, 1986) p. 1.

[35]Parker and Oglesby, p. 43.

[37]Parker and Oglesby, p. 45.

[38]Summarized from John D. Borcherding's discussion of work sampling errors in "Work Sampling," pp. 9-12.

[39]Summarized from John D. Borcherding's continued discussion of work sampling errors in "Work Sampling," pp. 9-12

[40]Borcherding, "Work Sampling," pp. 5-6.

[41]Parker and Oglesby, p. 48.

[42]Summarized from discussion of five minute ratings by Henry W. Parker and Clarkson H. Oglesby in Methods Improvement for Construction Managers, pp. 48-52.

[43]Parker and Oglesby, p. 54.

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[44]Parker and Oglesby, pp. 50-51.

[45]Borcherding, Effective Utilization of Manpower in Construction, pp. 30-31.

[46]Borcherding, Effective Utilization of Manpower in Construction, pp. 30-31.

[47]Borcherding, Effective Utilization of Manpower in Construction, pp. 30-31.

[48]Borcherding, Effective Utilization of Manpower in Construction, p. 46.

[49]Borcherding, Effective Utilization of Manpower in Construction, pp. 49-51.

[50]Borcherding, Effective Utilization of Manpower in Construction, pp. 49-51.

[51]Borcherding, Effective Utilization of Manpower in Construction, p. 31.

[52]Borcherding, Effective Utilization of Manpower in Construction, p. 31.

[53]Borcherding, Effective Utilization of Manpower in Construction, pp. 30-31.

[54]Borcherding, Effective Utilization of Manpower in Construction, pp. 30-31.

[55]Borcherding, Effective Utilization of Manpower in Construction, pp. 50-51.

[56]Borcherding, Effective Utilization of Manpower in Construction, pp. 50-51.

[57]Borcherding, Effective Utilization of Manpower in Construction, pp. 49-50.

[58]Borcherding, Effective Utilization of Manpower in Construction, p. 31.

[59]Borcherding, Effective Utilization of Manpower in Construction, pp 50-51.

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[60]Borcherding, Effective Utilization of Manpower in Construction, pp. 26-27.

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VITA

Captain Douglas Maurer is currently on active duty with the United States Army Corps of Engineers. A native of Lancaster, Pennsylvania, CPT Maurer graduated from J.P. McCaskey High School in 1974. He accepted admission to the United States Military Academy, West Point, New York, and received his commission on 7 June 1978 as a U.S. Army officer with a Bachelor of Science degree. CPT Maurer's initial tour of duty was in Karlsruhe, Germany with the 249th Engineer Battalion. While in Germany, CPT Maurer served as a project officer for over $500,000 worth of troop construction, as battalion design engineering officer, and as the officer-in-charge of all personnel and administration matters in support of 800 soldiers and their families. In December 1983, CPT Maurer assumed command of Company A, 802d Engineer Battalion located in Pyongtaek, South Korea. His unit provided heavy engineer equipment support in sustainment of a troop construction program valued in excess of $1.5 million. Following completion of his Korean duty tour, CPT Maurer entered the University of Texas Graduate School in September 1985 to study construction management.

CPT Maurer was born on May 31, 1956; he is the son of Mr. Paul E. Maurer and of Mrs. Robert Shank. CPT Maurer's military decorations include the Meritorious Service Medal and the Army Commendation Medal. He has completed the U.S. Army's military

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